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ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. III. 1883. Nos. 1 and 2.

PRACTICAL HINTS ON THE USE AND ABUSE OF ARTIFICIAL LIGHT.

By John Sobolewski, Member of the Engineers' Club of St. Louis.

[Read January 16 and 30, 1884.]

(Concluded from Vol. 2, p. 348.)

As the direct use of the standard cubic foot measure would consume immeasurable time in testing large meters, some of them requiring several hundred cubic feet to be passed through in order to determine their perfect working correctness under *all* openings, the Holder Meter Prover was constructed, and having water, same as in the standard cubic foot measure, as the base of resistance to the air expelled, the results obtained must be the same.

These Holders are constructed in various sizes to suit all sizes of meters, and mainly to bring them within reach of even the smallest gas companies or private corporations.

The meter is tested by this Holder on precisely the same principles as that of the standard cubic foot measure, only applied differently. As a matter of course the Holder is first rated by the standard measure. In operation it is as follows : In front of the instrument, a little below the base of the columns supporting the guide-wheel, is a valve, which, when opened, permits the air in the Holder to escape, and the Holder will sink down into the tank, which latter is filled with water to within six inches of the top ; a tube connected at one end with the valve and thereby with the outer air, passes down the inner side of the tank, thus forming a U-shaped siphon, rises up in the centre of the tank, touching the crown of the Holder or inverted bell when down, thus always remaining *above* the water in the tank. Now, by opening the valve and pulling down by the hand-grip in the chain on the left of the figure, the upper shell or inverted bell will rise out of the water and, as a matter of course,

the outer air (as nature abhors a vacuum) follows through the valve and U-shaped tube, thus filling the Holder with air. The valve is now shut off, and consequently the Holder full of air, and the air confined therein by the water in the tank pressing upward and the weight of the bell downward, it will be seen that by weighting the top of the bell any desired pressure may be obtained, which is registered by the gauge at the right of the valve.

The capacity in cubic feet of the Holder is indicated by a scale attached to the outside of the shell, and an adjustable pointer fixed to the top of the tank, to adjust to zero when ready for testing.

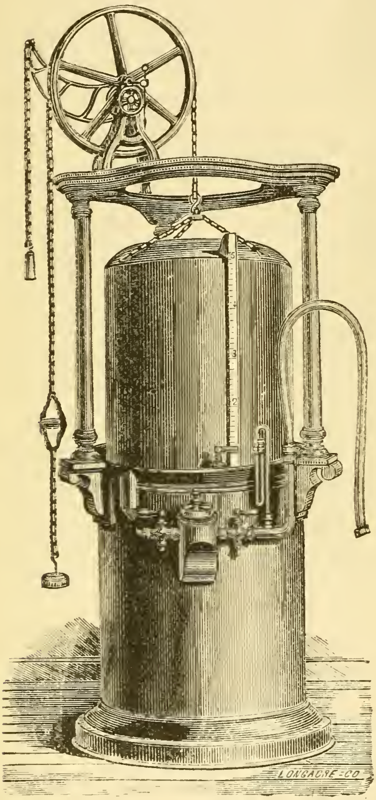


Fig. 6.

After being filled with air the meter to be tested is attached to the arched rubber tube seen at the right of the instrument, the connections are made air-tight, the lever-cock to right of valve opened, and the air from the Holder passes through the meter. As the bell descends into the outer tank the pointer indicates the number of cubic feet of air passed from the Holder into and through the meter, and the percentage of error, if any, is easily arrived at, *for example:*

Scale shows 1.9 cu. ft.
Meter registers 2.0 " " hence,
Meter shows plus 0.1 in 1.9 or in

$$1 \text{ cu. ft.} \frac{0.1}{1.9} = 0.0526.$$

Hence, in 100 = 100 × 0.0526 = 5.26 per centum *fast.*

Again: Scale shows 9.9 cu. ft.
Meter shows 10.0 " "

Difference 0.1 *fast* in 9.9, hence 0.0101 in 1 or 1.01 in 100.

Or: The meter registers 5 cu. ft. and scale 5.1 cu. ft.

Divide meter by scale, subtract product from 10000, cut off two right hand figures, result per cent. *slow.*

Thus: Meter. 5.0 cu. ft.

$$\text{Scale, } 5.1 \text{ " "} \quad \frac{5.0}{5.1} = 0.9805 \text{ or } \begin{array}{r} 10000 \\ -\ 9805 \\ \hline 1.95 \text{ per cent.} \end{array}$$

The scale on the Holder is so engraved that the percentages of error can be read off at a glance.

TABLE SHOWING THE PERCENTAGE OF ERROR IN METERS ACCORDING AS THEIR REGISTRATION DIFFERS FROM THAT OF THE TEST GAS-HOLDERS.

The sign + is used to indicate *fast*, and — to indicate *slow*.

Meters not exceeding 2 per cent. fast, or 3 per cent. slow, are correct within the meaning of the English *Sales of Gas Act*.

METER REGISTERING 2 FEET.		METER REGISTERING 2 FEET.		METER REGISTERING 5 FEET.	
Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per cent.
1.90	+5.26	2.01	—0.50	4.90	+2.04
.91	+4.71	.02	—0.99	.91	+1.83
.92	+4.17	.03	—1.48	.92	+1.63
.93	+3.63	.04	—1.96	.93	+1.42
.94	+3.09	.05	—2.44	.94	+1.21
.95	+2.56	.06	—2.91	.95	+1.01
.96	+2.04	.07	—3.38	.96	+0.81
.97	+1.52	.08	—3.85	.97	+0.60
.98	+1.01	.09	—4.31	.98	+0.40
.99	+0 50	.00	—4.76	.99	+0.20
2.00	Nil.			5.00	Nil.

METER REGISTERING 5 FEET.		METER REGISTERING 10 FEET.		METER REGISTERING 10 FEET.	
Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.	Reading of Scale.	Amount of Error.
Feet.	Per cent.	Feet.	Per cent.	Feet.	Per cent.
5.01	—0.20	9.90	+1.01	10.01	—0.10
.02	—0 40	.91	+0.91	.02	—0.20
.03	—0.60	.92	+0.81	.03	—0.30
.04	—0.79	.93	+0.70	.04	—0.40
.05	—0.99	.94	+0.60	.05	—0.50
.06	—1.19	.95	+0.50	.06	—0.60
.07	—1.38	.96	+0.40	.07	—0.70
.08	—1.57	.97	+0.30	.08	—0.79
.09	—1.77	.98	+0.20	.09	—0.89
.10	—1.96	.99	+0.10	.10	—0.99
		10.00	Nil.		

The foregoing, which can be verified by any gas consumer visiting the gas company and requesting to *see* these instruments and witness their operation, will plainly show the absurdity of attempting to prove the correctness of one meter by that of another, both subject to change as before alluded to. For nearly a year over 2,000 meters have been examined under my immediate supervision with a so-called "test meter" and a close and tabulated account kept of their action under such comparison, for I will not elevate this operation by calling it "a test." All probable precautions were taken to insure the most accurate results, the test meter was tested every morning *before* going out, on the meter prover just described, and any meters found varying greatly from the test meter, were ordered in for examination, the results on the prover being noted in a separate column opposite the results obtained by the test meter in place (meaning at the consumer's residence).

These tests, carefully conducted, have fully demonstrated the worthlessness of the instrument as a test meter, and I am prepared to show all kinds of results by this meter on the same meter tested, no two tests being alike, by changing the opening at the outlet.

When we recollect, that the test meter, which in this case is a "5-*light*," must make six revolutions to pass one cubic foot, and testing a "20-light" meter with it, which makes but two revolutions to pass one cubic foot, it is evident by the simplest laws of mechanics that there will $\frac{6}{2}$ or three times the amount of lost motion in the "5-light" which means likewise intermission of or loss in measurement, and will almost invariably show the "20 light" as registering fast—this error is increased as the meters to be tested are larger. Unscrupulous and irresponsible parties have taken advantage of this mechanical fact to attempt to convince gas consumers of the incorrectness of their meters, and success in isolated cases has lent color to the nonsensical theories they advanced. As an approximate indicator of the condition of a meter the instrument is of some value, and we continue the use of it on that account, as it enables us to compare every meter in use every three months, but as a test meter it can only increase the lack of confidence and the prejudice unfortunately existing on the part of the gas-consumer toward the seller. I cannot do better than to repeat the advice given in a former article: "Watch your burners; watch your pipes; watch your servants; and—read your meters every day."

GAS GOVERNERS.

The greatest annoyance to gas buyers and gas sellers alike are the constantly varying gas bills, principally due to the variations in pressure, as fully demonstrated in our former articles.

Numberless devices have been invented and constructed, all aiming for two widely different objects, namely: Regulators of Pressure and Regulators of Volume.

The first, or pressure regulator, is, as the name implies, intended to maintain at the outlet, while gas is passing, any desired pressure *below* that on its inlet, *irrespective of the volume* of gas being delivered in a given time—or, in other words, the number of burners used.

The second class are regulators of volume, intended to maintain a constant rate of delivery irrespective of variation of the inlet pressure, so long as this pressure is in excess of what is required to operate the instrument, and irrespective also, within certain limits, of the area of the final orifice of emission.

The pressure regulator is generally employed when a varying number of burners is used, while the volume regulator is adapted for single burners, or clusters of burners, only.

Both principles depend upon the following well established laws: That the volume of gas which will pass through and escape from an orifice in a given time is in compound proportion—

1st. To the area of the orifice.

2d. To the square root of the pressure of the gas.

3d. To the square root of the density or specific gravity of the gas.—King's Treatise, Vol. III., p. 44. London *Journal of Gas-Lighting*, Vol. XVIII., p. 722.

Prof. F. W. Hartley, Assoc. M. Inst. C. E., in King's Treatise, Vol. III., p. 44., describes the instrument as follows: "A regulator of pressure consists essentially of an inverted bell (or the equivalent of a bell, namely, a flexible diaphragm) dipping into and sealed at its lower end by some

fluid, which bell has suspended or attached to its centre a cone or valve, which is placed over or under a valve-plate on the inlet pipe of instrument.

The bell being weighted to give a certain downward pressure descends and opens the valve to an extent sufficient to maintain a pressure on the outlet of the regulator equal to that represented by the weights with which the bell is loaded, and the extent to which the valve will be opened will be proportionate to the ratios which the pressures bear to each other.

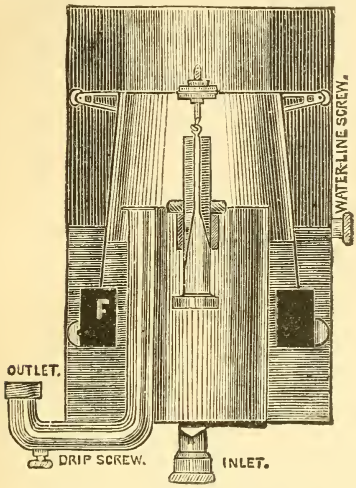


Fig. 7—Pressure Regulator.

The area of the outlet orifice will, when a regulator is in action, be equal to the combined areas of the holes of emission of the burners in use. If the total outlet area be small as compared with the full area of the valve, the bell will rise and nearly close the inlet orifice, and if the outlet area be increased the bell will descend and enlarge the area of admission, so that the volume of gas being delivered at constant pressure will vary with the conditions which affect the outlet side.

If, also, the *incoming* gas rises or falls in pressure, an immediate reduction or increase of the area of admission ensues.

The following tables, compiled from actual tests made by me for this article, will illustrate the consumption of a burner, with or *without* a governor, as also the regulating quality of the governor itself.

The instruments used in the test were *Sugg's Experimental Wet Meter*, with minute clock attachment (Fig. 3), a *horizontal double pipe*, so arranged as to throw the governor out and into action suddenly, a 5-*foot Meter Prover Holder* (Fig. 6), connected with bye-pass *burners*, to direct street supply, burners *without so-called checks*, being straight open pillars and tips only, and a *governor* constructed for this experiment and described as follows :

A is a cylindrical case, having a top cover.

B.—The case *A* has a central pipe or tube *C*, extending upward from bottom of case to near its top. The pipe *C* is open on top to allow the gas to enter into and escape from the case as the float rises or falls.

D is the float, closed at top and open at bottom, and held concentric with the vertical wall of the case by guide rollers, secured to the float by brackets *d'* working against the inner wall of the case.

On the lower portion of the float and inner side of the same is a crescent-shaped air-chamber *E*, its purpose being to sustain or to aid in sustaining the float in the glycerine with which the case *A* is partly filled. There is a great practical advantage arising from the use of an air-chamber of this described shape, in that the glycerine will not adhere to its surface, because of its inclination, and thus prevent the easy vertical movement of the float on the slightest variation of gas pressure.

F is the valve in the two-way case or shell F', secured to the bottom of the case *A* by flange *a*, and receiving and supporting the tube *C*, as shown. The valve is conical in shape, and is suspended by means of the stem *f* from the float *D*, to which it is secured by link-connection f', eye-screw f'', and nuts f''' f''. The valve is made conical so that it will be guided to its seat when the float rises. The link-connection is made so that should the float not rise or fall in an exactly vertical plane it will not affect in the least the valve. This class of regulators is too well known to need a description here of its operation.

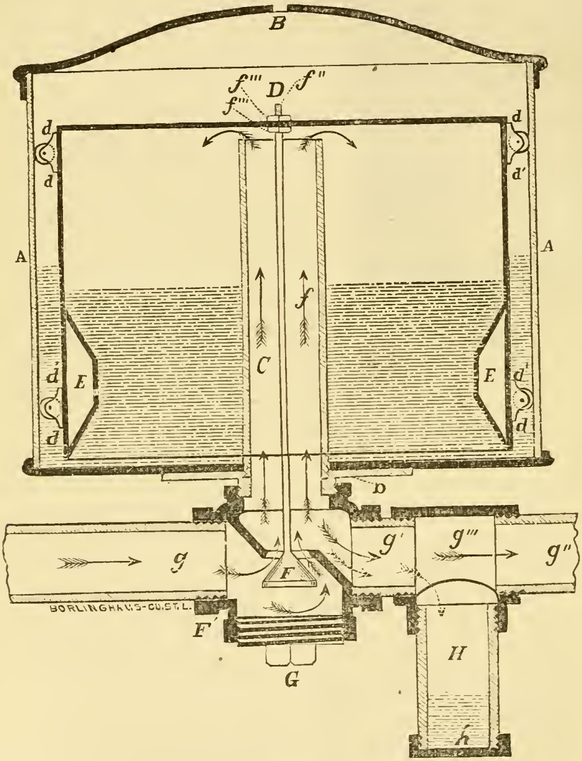


Fig. 8.—Garland Governor.

G is a plug in the casing or shell of the valve to allow easy access to the inside of the valve for the purpose of cleaning the parts.

g is part of the supply-pipe, and g' g'' parts of the eduction-pipe. Between the sections g' and g'' is a coupling g'''.

H is a drip-cup connected to the coupling g''' of the outlet-pipe of the machine. The purpose of the drip-cup is to receive all condensations which otherwise would pass into the machine, gumming up and interfering with the operation of the parts.

The cup is provided at bottom with a means for allowing the escape of

condensed matter. I have shown a removable bottom *h* for this purpose, but a common cock may be used.

It will be seen that this drip cup, by its location, receives condensed matter from all parts of the regulator.

TABLE NO. 1.

Consumption of gas in cubic feet per hour of burners burning without governor and under varying pressures :

No. of Burners.	Street Pressure in tenths of one inch.	Pressure at point of combustion in tenths of one inch.	Consumption of cu. ft. per Hour.	At Rate of 1 Burner per Hour.
10	5	3	32.5	3.25
10	10	7	48.8	4.88
10	15	11	58.8	5.88
10	20	15	68.0	6 80
10	25	18	73 5	7.35
10	30	21	75.0	7.50
10	35	23	76.2	7·62

TABLE NO 2.

Same burners as in No. 1. with governor in action, and weighted to 4½-10 pressure at outlet.

No. of Burners.	Pressure at Inlet in tenths of one inch.	Pressure at Outlet in tenths of one inch.	Cons. of cu. ft. per Hour.	Rates per Burner.
10	5	4.0	31 25	3.1
10	10	4.5	33.0	3.3
10	15	4.5	33.0	3.3
10	20	4.5	33.0	3 3
10	25	4.5	33.0	3.3
10	30	4.5	33.0	3.3
10	35	4.5	33 0	3.3
10	40	4 0	31.25	3.1
10	45	4.5	33.0	3.3
10	50	4.0	31.25	3.1
10	55	4.5	33.0	3.3
10	60	4.0	31.25	3.1

TABLE NO. 3.

A new set of burners, with governor weighted to 15-10 of one inch pressure at outlet.

No. Burners.	Inlet Pressure in tenths of one inch.	Outlet Pressure in tenths of one inch.	Consumption in cu ft. per Hour.	At Rate of 1 Burner.
10	6	5	32	3.2
10	12	9	46	4 6
10	13	10	48	4.8
10	20	16	60	6.0
10	22	15	58	5.8
10	24	15	57	5.7
10	34	15	57	5.7

TABLE NO. 4.

Lighting burners successively, beginning nearest governor, weighted to 8-10 of 1 inch.

No. Burners Lighted.	Inlet Pressure in tenths of one inch.	Governor Pressure in tenths of one inch.	Pressure lost by increase of friction.
1	51	8	..
2	51	8	...
3	50.5	7.5	0.5
4	50	7.5	0.5
5	49	7.5	0.5
6	"	7.0	1.0
7	"	6.5	1.5
8	"	6.0	2.0
9	"	6.0	2.0
10	"	5.5	2.5

By extinguishing the lights in succession, beginning nearest to governor, the action was reversed.

To show the admirable action of this governor in sustaining the press sure at the outlet I call attention to table No. 2. With ten burner-lighted and 60 tenths pressure at inlet the governor held the outlet pressure at 4 tenths, and adjusted itself instantaneously in suddenly changing the pressure from inlet to outlet, and *vice versa;* showing not the slightest jumping or vibration—while the maximum difference in outlet pressure, as shown in Table No. 4, between one burner and two burners was 2 1-2 tenths. A more sensitive instrument I never tested.

From the foregoing tables the following deductions may be drawn:

1. The discharge of gas will be doubled by application of four times the pressure, or reducing the length of the pipe four times.

2. The discharge of gas will be only one-half when the pressure is four times diminished, or length of pipe four times increased.

The consumption of burners will also vary if the governor is not on the same level with the burners intended to be governed, and the pressure on the floors above the governor will be greater on account of the natural lightness of the gas by about one-tenth of an inch for every ten feet rise, and if burners are turned off in the upper floors the tendency will be to increase the pressure on burners, and consequent greater consumption on the lower floors (see table No. 4) and *vice versa*, simply because it is gas *in motion* and subject to the laws of the *flow of gas.*

These experiments are fully corroborated by Prof. Hartley, who says:

"It is quite manifest that a governor cannot maintain equality in the rate of consumption, per burner, when the number of burners is varied, and when the gas is transmitted through pipes. A loss of pressure must arise from friction, which loss, all other things being equal, will vary with the rate of discharge. When the largest number of burners is in use the difference between the *acting* pressure of the governor and the pressure at each point of discharge will be at its maximum; but as the number of lights is diminished so will the difference be reduced, and the pressure at the burner will be increased. (See table No. 4.) It might be thought, perhaps, by any one not well informed, that if such an effect as that last mentioned takes place, the governor can be of little value; but

a moment's reflection will show the error of such an opinion. * * * It has already been shown that the governor will regulate to the extent of *preventing the pressure rising higher* in its outlet than that of its own acting force." (See table No. 3.)

It may be well to state here that no gas company is responsible for any accidents occurring where governors are employed. Parties selling these often attempt to make use of this rule to their advantage by representing that gas companies object to the introduction of governors on account of their cutting down gas bills; but this is not the case, as every gas company would be glad to encourage its consumers in the proper use of gas; but in the majority of cases the most villainous machines are forced on to the company's meter, destroying the thread of the screws, bending the meter connections until they are almost useless, causing leakage and consequent loss of gas and often reducing the light when most wanted.

Of course the first rush, in such a case, is to the gas company's office: a complaint is made that the gas will not burn, although the house next door may be brilliantly lighted; all the fault is thrown on the gas company, for *they* can be found, always ready to correct all difficulties. But where is the governor-man?—where?—like last winter's snow—gone. The machine has to come off, the meter must be changed, as the screws are cut and spoiled; the connections also; the burners are all open, checks all taken out by the economical governor-man; the gas flows through the burners like a mill-race; and the man paying the bills probably dies of despair or heart disease, cursing the gas company as the cause of all this mischief.

A decent governor and a decent man selling or renting it, where conditions warrant its use, will save money and give a steady, enjoyable light; but beware of mountebanks advertising machines that will give you four times as much light as you ever had before, for four times less money, like the pictures of the patent medicine-man "*before* and *after* taking."

As in many other things, it is a safe rule to go by that if you want plenty of light you must use plenty of gas. the point of economy is: turn down your lights when not wanted; while all experiments clearly point to the fact that economy must come in at the point of combustion, the burner must be so improved as to become a perfect regulator of volume, and until this is accomplished care and attention to the height of flame will save many dollars and many hard and unjust aspersions upon gas companies.

All this clearly indicates that a governor can only act economically when the pressure is greater in the street mains than is requisite at the burners, which, during the heavy winter consumption, is rarely, if ever, the case: and this also accounts for the fact that the governor-man seldom attempts to sell them as winter approaches, but appears with the spring blossoms.

It also points out the necessity of observing certain precautions wherever a governor is employed.

As the outer shell is filled with fluid this fluid must be anti-freezing, and, as much as possible, non-evaporative. Should the fluid become

so low that the pressure of the gas inside the inverted bell will overcome its weight the gas will blow out through the water, or, as it is called technically, "break the seal," escape into the premises, and possibly cause death or explosion.

Should the water accumulate from deposits of aqueous vapor and condensation of the gas the dry-well will become filled, the water will close the gas passages and the lights will go out. This may happen at night: in fact, it generally does—night lights or vault lights in banks may have been left burning and accidents may possibly happen. Any sudden pulsation in the governor will produce the same results.

Should the metal in the shell or bell corrode, or by some blow become damaged, leaks of gas will take place, with perhaps dangerous results.

All these possibilities are known to sellers of these machines, and therefore but few of them are now sold outright, excepting to parties fully acquainted with their manipulation and use. The majority of them are rented out on monthly payments, the seller holding the ownership of the machine and taking care of same.

The dry or diaphragm governor is constructed on the same principles as the wet, excepting that in place of the inverted bell carrying the conical valve a flexible diaphragm, generally composed of prepared leather, is drawn across the lower half of the gas chamber; from the centre of this the valve is suspended; as the gas enters underneath the diaphragm it lifts or inflates it, raising the valve and closing the opening of the outlet in proportion to the weight on top of the diaphragm.

Being constantly exposed to the action of the atmosphere, heat from furnaces, boilers, etc., the oil in the leathers soon dries out, they become stiff and hard, refuse to act and are finally thrown out. As yet no flexible substance has been found, leather, rubber or otherwise, through which gas will not premeate more or less, and hence the dry governor can generally be traced by the olfactory organs.

Should the leather crack, or by some accident be broken, there is no chance of water overflowing and shutting off the gas, as in a wet governor, but a full opening will be given for its escape, and with most dire results.

Where excess of pressure exists, which cannot be readily controlled, as in hotels, theatres, churches, etc., and governors must be employed, the wet governor should be used, and that of the most improved make, with a guarantee by the seller to attend to it and examine it regularly.

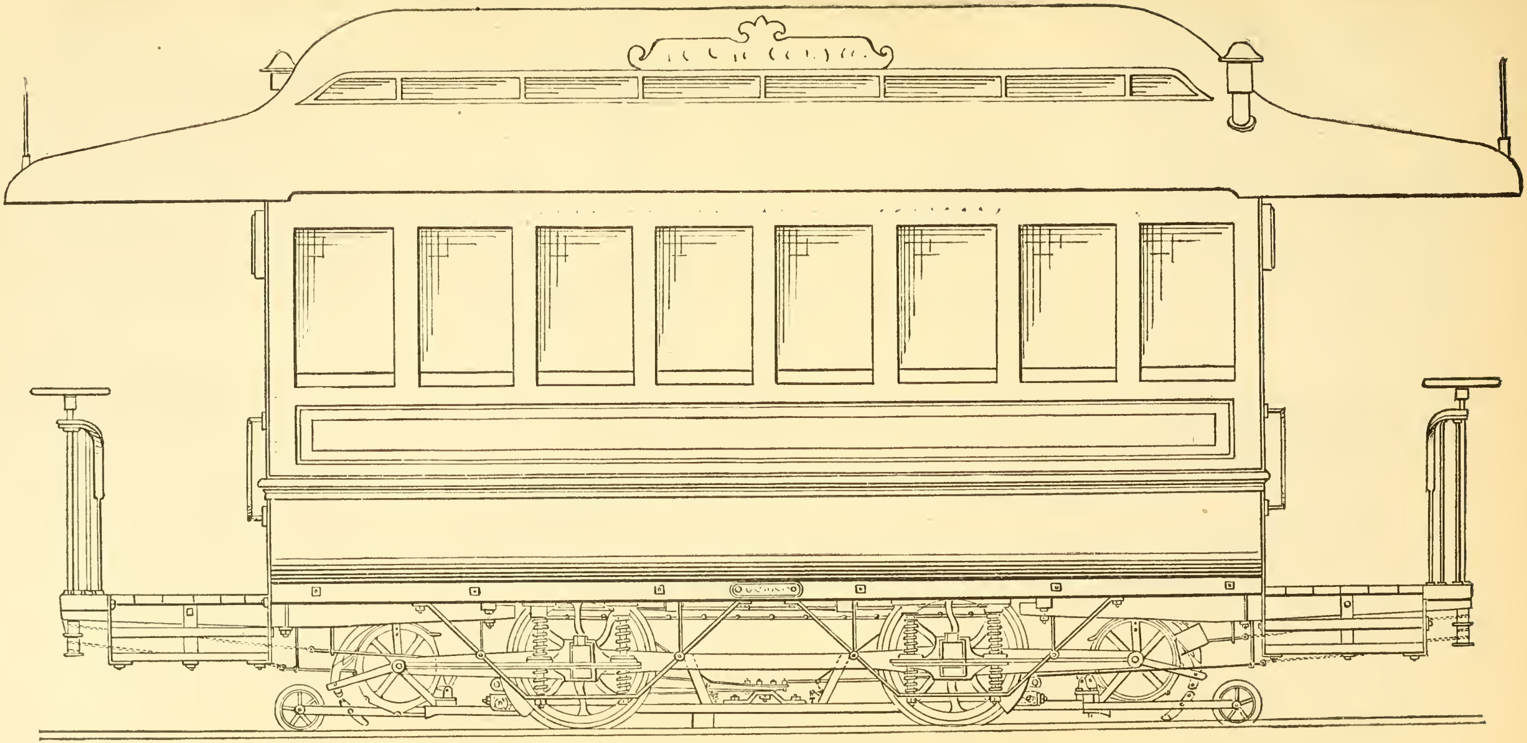
CABLE PROPULSION FOR STREET RAILWAYS.

By Augustine W. Wright, Member of the Western Society of Engineers.

[Read January 15, 1884.]

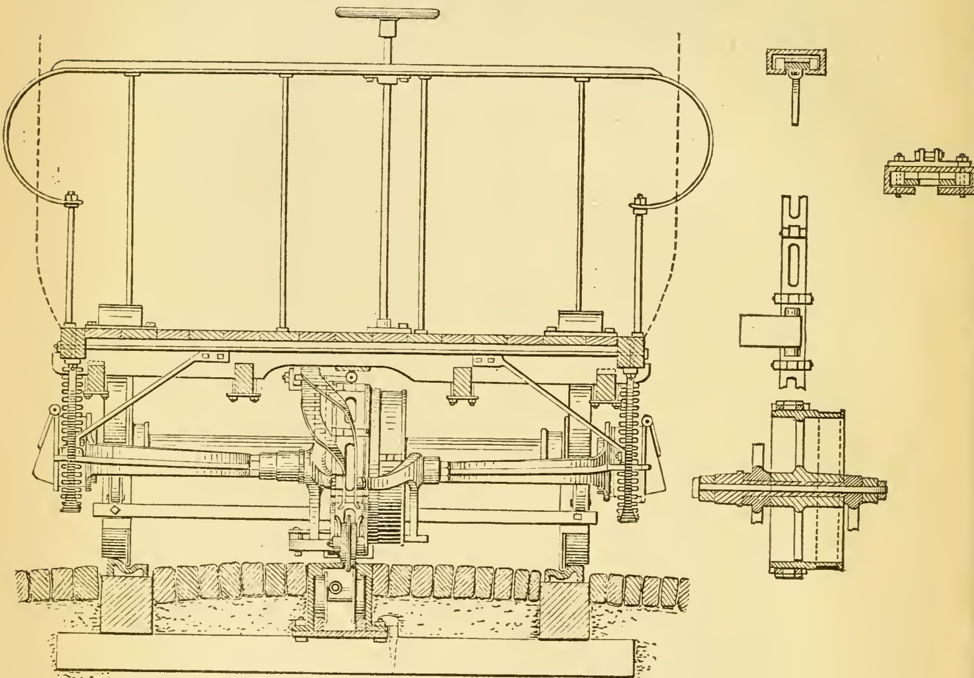
As a member of your "Committee on Transportation, etc.," I have the honor of addressing you upon a system of cable propulsion for street railways.

I would premise my remarks by the statement that street railways are an American idea, and the first charter was for the New York & Harlem, opened in 1832. From this beginning they have spread to nearly every quarter of the globe.



A.

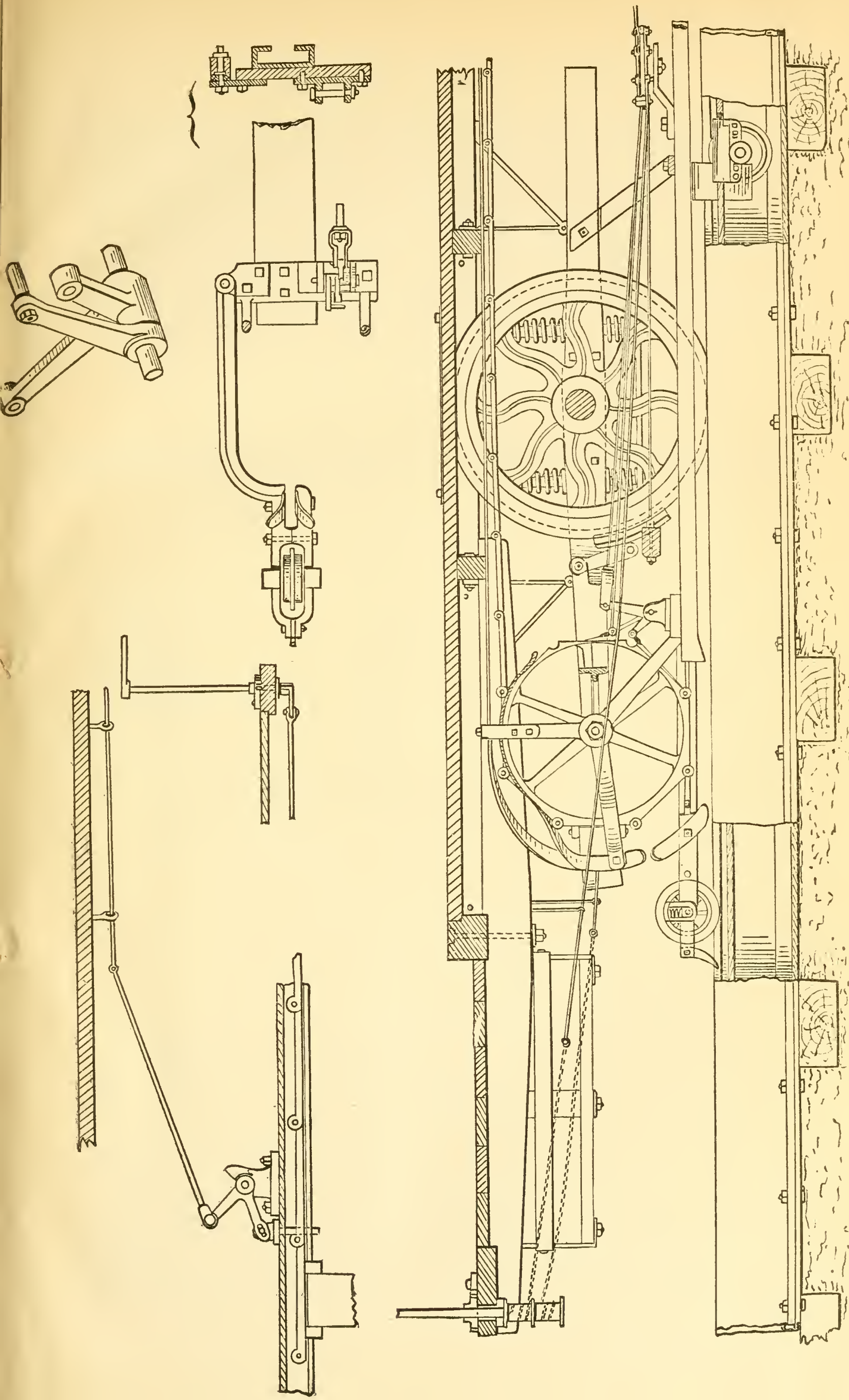
Hon. Moody Merrill, in his address at the organization of the American Street Railroad Association in Boston, Mass., December, 1882, said: "There are now organized and doing business in this country and Canada 415 street railroads. They run 18,000 cars. * * * More than 100,000 horses are in daily use. * * * To feed this vast number of horses requires annually 150,000 tons of hay and 11,000,000 bushels of grain. These companies own and operate over 3,000 miles of track. * * * The whole number of passengers carried annually is over 1,212,400,000. The amount of capital invested in these railways exceeds $150,000,000. These figures give you an idea of the vast importance of



B.

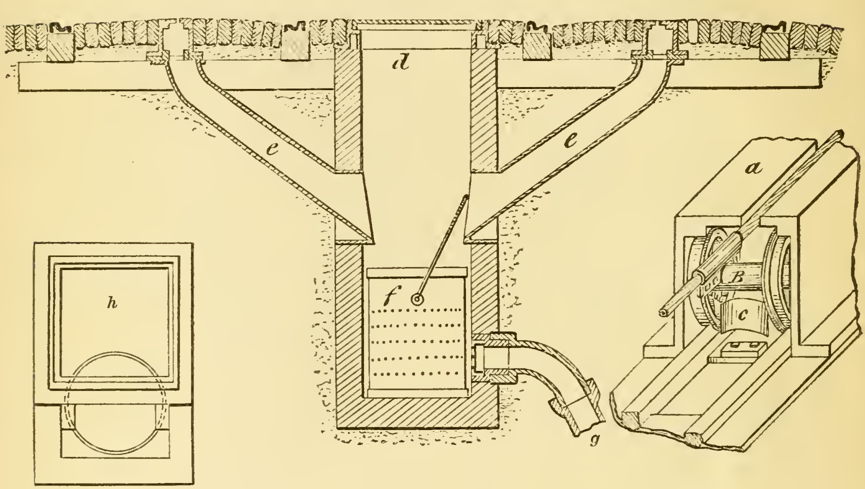
this business and the great expense of horse power therefor. Inventors have been at work for years to find some method of doing this work without horse power, and many patents have been taken out. Compressed air, electricity, gas engines, compressed steel springs, endless wire cable, etc., have been proposed.

"Sir F. Bramwell reports favorably of the Mekanski compressed air system as used on the Nantes Tramway in France, as does also B. Frank Teal, of Philadelphia, but compressed air was not a success as tried by the North Chicago City Railway. The electrical motor can hardly be said to have yet passed the experimental stage. Among the applications of gas engines is the patent of B. C. Pole. This motor weighs 4,000



C.

lbs. The force is obtained from an Otto or similar gas engine. After its injection into the engine it is exploded, and the explosion operating upon a series of pumps or valves sets in motion the movements of the motor. In the first place there are two fluid cylinders so arranged as to bring the pressure upon a foot which goes down upon the cobble stone between the tracks, making a step of 3′—2″ in length; and every time this grip-like device, fitted with teeth and nicely adjusted for securing purchase, or hold, makes a step the motor is pushed forward 3′—2″, the step to be decreased or increased by regulation from the engineer. The



D.

foot is padded with rubber which gives its stroke such elasticity that that there is no jar or sudden start." *Railroad Gazette*, p. 114, 1883.

I invite your attention to the accompanying cut of a machine, patented by David Gordon, December 18th, 1824, in England. Substitute steam for gas, and you have a very similar idea.

The Baldwin Locomotive Works manufactured steam motors, but any machine depending upon its *adhesion* upon the unfavorable street rail is at a disadvantage. It must be made so heavy that rapid depreciation results to itself and the tracks, for the latter are covered frequently with a greasy mud that reduces the adhesion probably to less than one quarter of that obtained on a "T" rail. Herein is the chief advantage of the system of stationary engines and ropes. As you are aware, in 1829 the

directors of the Liverpool & Manchester Railway Co. submitted to Messrs. Rastrick, Walker and Stephenson, three most eminent English engineers, the question: "What, under all circumstances, is the best description of moving power to be employed upon Liverpool & Manchester railroad?" Rastrick and Walker replied: "Upon the consideration of the question in every point of view, taking the two lines of road now forming, and having reference to *economy*, *dispatch*, *safety* and *convenience*, our opinion is that if it be resolved to make the Liverpool & Manchester Railroad complete at once, so as to accommodate the traffic stated in your instructions, or a quantity approaching to it, the stationary reciprocating system is the best." This was stationary engines and ropes, and thus in the early days of railroading was stationary engines proposed, but it was not until modern inventors had perfected the manufacture of wire rope that the system was applied to street railways. Among the many patents upon this subject in the United States of America are those of General Beauregard, A. C. Beach and A. S. Halliday, of San Francisco, Cal., who is entitled to great credit for the success of the cable-roads there, inaugurated August, 1873, by the Clay Street Hill Railroad Co., and subsequently adopted by other roads in San Francisco, and the Chicago City Railroad Co. here. Oct. 3d, 1882, you had the pleasure of listening to an interesting paper by our fellow member, D. J. Miller, upon the construction of the latter road.

I now desire to call your attention to the system of endless wire rope propulsion patented by Charles W. Rasmussen, owned by the United States Cable Railway Co., of this city. It possesses novelty and, in my opinion, many advantages. The plan marked *A* shows very plainly his system of track construction. To the cross-tie of the tracks as ordinarily laid he spikes a tube of channel iron in the centre between the car wheel rails. This tube is the same depth as the ordinary stringer and rail, *i. e.*, eight inches for the former, one inch for the latter, or nine inches. It has a slot open on top ⅝ inch wide, or the same as the Halliday system. In the bottom of this channel you will notice a rail on each side. Instead of carrying his cable upon stationary pulleys, he attaches to the cable each sixteen feet, by a suitable clamp, an axle, having two wheels six inches in diameter, upon which it travels. As often as may be necessary he also attaches to the cable a broom or scraper to clean the tube of all snow, ice or dirt that may enter it through the open slot. At suitable intervals the bottom is left out of the tube, and inclines built carrying this dirt into iron boxes or pails placed in catch-basins built between the tracks, if it be a double-track road. These can be removed from time to time as may be necessary. He has perfected plans by which curves are turned and tracks crossed upon a level. So much for the substructure. The device by which he propels the cars is most ingenious. Under the bottom of each car, at each end, he fastens a wheel, around both of which passes an endless steel band. To the latter are attached by hinged joints, plates of steel about 9 inches long and deep enough to reach into the aforementioned slot and engage one of the axles attached to the cable. These arms and axles are so arranged as to meet each other like cogs upon wheels. When the *car* is standing

still these arms revolve around under the car with the same speed as the cable. The conductor signals the driver to start. He gradually tightens this band by a friction clutch, and the car slowly or quickly starts as the friction is applied slightly or more firmly.

The advantages possessed by this system, in my opinion, over any other system of wire rope propulsion with which I am familiar are briefly as follows :

1. Cheapness of construction. The Chicago City Railroad cable track is reported by its President to have cost $105,000 per mile of single track. The tracks of the North Chicago City Railroad Co. at present prices cost per mile of single track $9,004.21 paving 8.0 wide, $6,279. The channel for this cable will weigh 172 tons and @$55 per ton, =$9,460 ; 440 axles and wheels @1,50=$660; cable, @25 per ft., $1,320; 16 catch basins @10=$160; labor of laying and spikes $300. Total cost of one mile single track on this plan $27,183.21, of which sum $11,900 is for the cable.

· This system permits of being laid without tearing up horse-car tracks and consequent loss of revenue during construction. No interference with gas and water pipes or sewers. In operation there is not the expense of constructing and maintaining grip cars, affording as they do small seating capacity, and this not used during winter weather. This grip is attached to each passenger car at an estimated cost of $150. The driver is placed at the front end of the car where he has an unobstructed view of the track, and can avoid accidents to individuals and vehicles. Only one hand-wheel is required to operate both grip and brake. The same turn of this wheel releases the cable and applies the brake or the reverse as the case may be. The cable is always in line. There is no *downward* strain on the car caused by lifting the cable above carrying pulleys and consequently making a doward pull, very detrimental to track. The great danger of cutting the cable by a carelesss or negligent driver neglecting to "let go" at the proper points is avoided, and it is impossible to miss connection with the cable. There is no wear on the cable when the car is stationary. It is not sliding through a grip. This must prolong the life of the cable many times. Should the tracks be obstructed by fire hose or any other means these cars can be transferred to the other track, and run backward and forward on each side of the break, and if the cars are "bunched" by any accident, the cable can be run faster, and the delayed cars can make up time while the others can travel slower than the cable with slight wear upon them and none at all upon the cable. This is not the case when the cable is slipping through grips and rapidly destroying the latter as well as itself, as in the San Francisco system. If their track be obstructed, all the cars must remain stationary. They cannot let go the cable and regain it except at certain prepared points upon the line where the cable is elevated; ordinarily it is below the grip that the latter may pass over the carrying pulleys. No skill is required to manage the Rasmusen grip. Any one who can turn a wheel can manage the car, and the company is not consequently at the mercy of some evil-minded employé who inaugurates a strike. Not so when skilled labor must be employed.

I will not submit an estimate of the comparative cost of cable traction and horse-power. It varies with each situation and the relative prices of

the various items going to make the total. The following table is taken from the return of three companies to the State Engineer of New York for the year ending Sept. 30, 1882:

Name of Road.	Number of Horses.	Repairs of Harness.	Horse Shoeing.	Cost of Horses.	Stable expenses.	Cost of Feed.	Water taxes.	Total expenses, 1882.
Sixth Ave...	1252	$6,600.53	18,581.26	$72,005	$83,240	$141,297	398	613,984
Eighth Ave.	1150	4,975.02	18,065.51	40,453	54,739	138,197	557	495,144
Third Ave..	1931	5,135.98	25,627.99	70,662	4,759	237,648	...	878,922

From this report it appears that the average expense of each horse was $213 during that year; that the cost of the horse department was 46 per cent. of the total operating expenses, and to reduce this great expense is the effort of those who advocate the cable system of propulsion. The Committee on "Motive Power" reported at the October, 1883, meeting of the Street Railroad Association regarding cable railroads: "This system, in our judgment (though in its infancy now) is on the right road to solve the problems of dispensing with animal power. * * * We believe, in conclusion, that the only practical means presented to our view for dispensing with animal power is the cable system * * *"

The cable system is awakening a widespread interest, and I take pleasure in bringing this plan before you, and hope it may be discussed. I shall be glad to furnish any further information in my power.

Of the accompanying plans "A" shows a side view of car and grip, "B" an end view of same, "C" a side view of one end, with details; "D" the method of building the aforementioned catch-basins. The plans are so plain they can scarcely require detailed explanations.

LATERAL SYSTEMS FOR IRON PRATT TRUSS HIGHWAY BRIDGES.

By Prof. J. A. L. Waddell, Member of the Western Society of Engineers.

[Read February 5, 1884.]

The bridges treated of in this paper are those of most economic depth and panel length, which dimensions have been already presented to the Society in a paper upon "Economy in Highway Bridges." In the accompanying table the dimensions given in the columns marked *Pan.* 1 are the sections respectively of the upper portal struts, the portal vibration rods (if any), the lower portal struts (if any) and the lower lateral rods. Those given in the other columns are the sections respectively of the upper lateral struts, the upper lateral rods, the post vibration rods (if any), the intermediate struts (if any), and the lower lateral rods. The portal struts are thus assumed to belong to the first panel, the first intermediate upper lateral strut with its sway bracing to the second panel,

etc., so that when the bridge has an odd number of panels there is no lateral strut or vertical sway bracing given for the middle panel. The 40', 50' and 60' spans being pony trusses have only lower lateral rods.

Spans above 150' in length have vertical sway bracing.

The wind pressure assumed is forty pounds per square foot for spans of one hundred feet and under, thirty-five pounds for spans between one hundred and one hundred and fifty feet including the latter, and thirty pounds for all greater spans. It is true that actual wind pressures do occasionally exceed these amounts, but in view of the fact that the chances of any one bridge ever being subjected to such pressure throughout its whole length are extremely small, and that it could receive once in a while a far greater pressure without suffering material injury, if the bridge be properly designed, it seems legitimate to adopt the pressures assumed. Moreover, when a highway bridge is blown down the actual loss is seldom greater than the value of the bridge. Travelers can cross the stream at the nearest bridge above or below until the structure be replaced; and the fall of the bridge need involve no loss of life, for in the first place no human being would be likely to be upon it in such a storm, and, in the second, if there were, he could not escape being dashed to pieces or blown off, even if the bridge were sufficiently rigid to withstand the pressure.

With railroad bridges, of course, it is a very different matter. The delay caused by the loss of a bridge may be much more expensive than the replacing of the structure ; besides, railroad bridges are subjected to the greatest wind pressure when covered by a train, so that the fall usually involves the loss of human life.

If the lateral systems of highway bridges were to be made as strong as those of railroad bridges, eye bars could be very seldom employed for the bottom chords, because the compression there due to the wind pressure would be far in excess of the tension due to dead load. Even with the pressures assumed, it is necessary to rely upon the stiffness of the joists to prevent buckling the bottom chords of at least two-thirds of the iron and combination highway bridges in the United States. Upon this point the writer would refer to an editorial in the *American Engineer* of July 20th, 1883, upon "A Neglected Consideration in Highway Bridge Designing," where the effect of wind pressure upon bottom chords is mathematically discussed. In the discussion the effect of initial tension in the lateral rods is neglected ; so the actual compression on the windward bottom chord is even greater than there calculated.

If any bridge designer object to relying upon the joists to prevent chord buckling, it will be necessary for him to stiffen the chords from end to end. An easy method of accomplishing this object would be to truss the two inner chord bars. The compression members thus formed would be neither very elegant nor very strong, but they would be effective enough in resisting the surplus compression. Instead of designing highway bridges to resist the greatest recorded wind pressures is it not better to run the risk of occasionally losing a structure than to make all the bridges so much more expensive?

Exception should, of course, be made for highway bridges in unusually exposed situations.

The writer wishes it to be distinctly understood that in advocating the adoption of low wind pressures he does not countenance the building of such miserable apologies for lateral systems as one finds in the majority of highway bridges. I beams are not fit for upper lateral struts, especially when they have jaws at their ends, nor should $\frac{5}{8}''$ rods be employed anywhere in a bridge.

Some of the most flourishing highway bridge companies never figure at all upon the effect of wind pressure, but content themselves with using rods from $\frac{5}{8}''$ to $1''$ in diameter for all spans under $150'$ in length, and I beams or even pieces of gas-pipe for lateral struts. It is not necessary to add any area to the section of the bottom chord to resist the tension due to wind pressure, unless this tension exceed that due to the live road: for, as before stated, there is no likelihood of travel during heavy winds. nor are any loads ever supposed to remain upon a bridge for any length of time.

For this same reason the bending effect of the wind upon posts and batter braces is neglected, unless it produce a greater stress than that due to the live load.

But the bending effect upon portal and lateral struts, where no vertical sway bracing is used, is much greater than the effect of the direct pull of the lateral rods. It is only lately that the writer has fully appreciated the magnitude of the bending stresses in these members.

The area of bridge per lineal foot was calculated from a number of diagrams of stresses and sections, and was divided between the upper and lower lateral systems by supposing a horizontal plane to pass through the middle of the posts, and assuming that all the pressure above this plane is carried by the upper lateral system and all below by the lower lateral system.

This may be a correct assumption and may not, but it is as likely to be correct as any other. Where vertical sway bracing is used the division of wind pressure becomes still more ambiguous, but, as before, the same assumption is as likely to be correct as any other.

In calculating the area exposed to the wind the area of the vertical projection of one truss, hand rail with its posts, hub-plank, guard rail and the rectangles described about the ends of the floor beams was doubled, and to this was added the area of the vertical projection of the floor and joists.

As the windward hand rail and hub-plank would probably fail the total area thus found is somewhat too great; but such a failure should not be depended upon when the wind is considered to strike the bridge suddenly.

The areas thus found vary between 6.8 and 7.6 square feet per lineal foot for the portion of the structure below the middle horizontal plane. For spans of two hundred or two hundred and thirty feet and under, the sizes of the upper lateral rods were not determined by the effect of the wind, as this method would make them smaller than experience would indicate to be necessary to give sufficient rigidity to the bridge.

The wind stresses on the lateral rods were calculated for a moving load instead of one upon the whole bridge, because this method causes

the rods toward the centre of the span to be somewhat increased in diameter; besides, it is possible for a portion only of a structure to be subjected to wind pressure, the rest being protected by a hill, a building, or some other neighboring object.

The method of calculating the stresses in the vertical sway bracing is as follows: it is essentially that of Prof. Burr as given in his treatise on "Stresses in Bridge and Roof Trusses." The reason why the demonstration is given here is because of a few changes introduced by the writer.

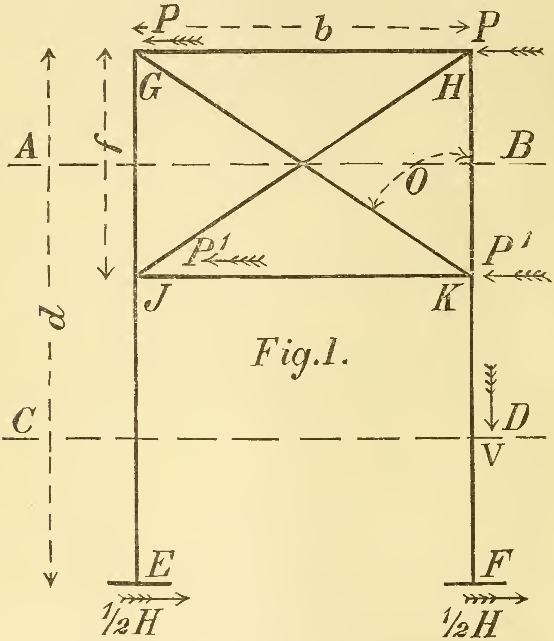


Fig.1.

In Fig. 1, let P be the pressure supposed to be concentrated at the upper panel point on one side of the bridge. It is that which comes upon a panel length of top chord, one-half the area of the diagonals meeting at the panel point, and the portion of the post above the plane A B. Let P' be the pressure concentrated at one end of the intermediate strut. It is that which comes upon the portion of the post between the planes A B and C D, the latter passing half way between the intermediate strut and the bottom chords. If the intermediate strut should be at the middle of the post, and the main diagonals and counters be coupled on a pin at this point, it would be necessary to divide the pressure upon the main diagonals and counters between the upper, middle and lower points of the posts, the middle point taking one-half, and the others a quarter each.

Let d = depth of truss.

f = vertical distance between upper lateral and intermediate struts.

b = distance between centre of trusses,

and θ = angle made by vibration rod with the vertical.

The pressures concentrated at the lowest points of the posts do not affect the sway bracing, so are not considered.

The total pressure $2(P + P') = H$ is assumed to be equally resisted by the feet of the posts. It is possible that this assumption is incorrect, for one foot may resist more than the other, but when it is considered that perhaps the whole of the force $2P$ passes through the upper lateral system to the pedestals at the feet of the batter braces it will be conceded that the assumption is not on the side of danger.

If the whole of $2(P + P)$ were to be resisted by the feet of the posts, the functions of the upper lateral system would be rather limited, nearly the whole of the wind pressure upon the structure being then carried by the lower lateral system. If such were the case, the lower lateral systems given in the table would all be too weak, which is not likely to be so, for they are much stronger than those usually found in highway bridges. But whether the wind pressure upon the upper part of the trusses is resisted by the upper or by the lower lateral bracing, it is better as far as the sway bracing is concerned to proportion it, under the supposition that the pressures at the upper panel points are carried thereby to the feet of the posts.

Taking the centre of moments at E, the moment of the wind pressure is $2\,Pd + 2\,P'\,(d - f)$, which can be resisted only by the moment of a released weight V upon the foot at F, thus

$$2\,Pd + 2\,P'\,(d - f) = Vb$$

$$\text{and } V = \frac{2d(P + P') - 2P'f}{b}$$

This release of weight V must pass up the vibration rod KG, causing a tension therein equal to $V \sec.\theta = \frac{2d\,(P + P') - 2\,P'f}{b} \sec.\theta$.

To find the stress on the strut JK pass a plane through the sway bracing cutting GH, GK and JK, take the centre of moments at G and consider the forces acting on the left side of the truss, then the moment of the stress in JK will balance the moments of P' and $\frac{1}{2}H$, thus $(JK) = \frac{\frac{1}{2}Hd - P'f}{f} = \frac{d}{f}(P + P') - P'$, to which must be added the horizontal component of the initial tension in JH.

The stress in the upper lateral strut GH is that due to the wind pressure, considering it as a portion of the upper lateral system plus the sum of the horizontal components of the initial tensions in the three rods meeting at one of its ends.

These formulæ may be used for the portal bracing by putting for d the length of the batter brace, for f the distance between centre lines of upper and lower portal struts, for P' the pressure on one-half of the batter brace and for P one-half the reaction of the upper lateral system, including the pressures concentrated at the hips.

The division of P between the two sides does not affect the stresses in the lower strut and vibration rods: it affects only that in the upper strut, which is equal to the transverse component of the stress in the end lateral rod plus the pressure concentrated at one hip plus the components in the direction of its length of the initial tensions in all the rods meeting at one end. For any span where the size of the end lateral rod was assumed the stress in the rod is to be calculated by multiplying the area of its sec-

tion in square inches by the intensity of working stress, which is seven and a half ($7\frac{1}{2}$) tons, and omitting its initial tension.

As the stress thus found for the upper portal strut is only a little in excess of that found for the lower the size of the latter has been made equal to that of the former in the table. When there is no vertical sway bracing stiffness is obtained by the use of knee braces or brackets AB, CD, Fig. 2, making angles of about forty-five degrees with the vertical. Let the notation be as shown in the figure, V being as before the relief of weight at F. P is the sum of the pressures at K and G. Taking the centre of moments at E gives

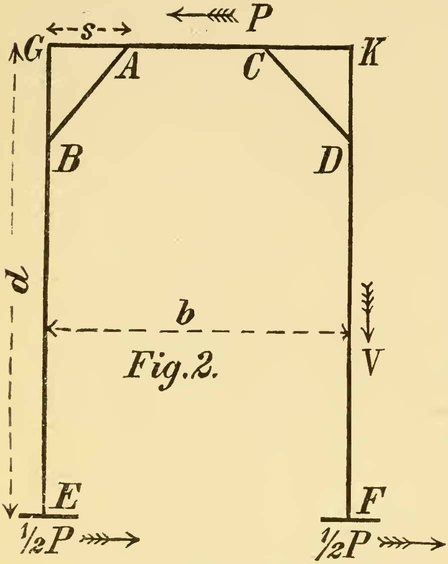


Fig. 2.

$$Vb = Pd \text{ and } V = \frac{Pd}{b}$$

Again, taking centre of moments at A gives the value of the bending moment M on the strut at that point, thus

$$M = \mathrm{V}\,(b - s) - \tfrac{1}{2}\,Pd = \frac{Pd}{2b}\,(b - 2s.)$$

Let h = the distance between the centres of gravity of the two channels of which the upper lateral strut is composed, then the bending stress

$$C = \frac{M}{h} = \frac{Pd}{2\,bh}\,(b - 2s).$$

The intensity of working bending stress for this case was taken equal to six tons, so that $\frac{C}{6} = \frac{Pd}{12\,bh}(b - 2s)$ = the number of square inches of area to be added to each channel in order to resist bending.

The intensity of direct working stress was taken from the well-known formula $p = \dfrac{\dfrac{f}{1 + \dfrac{H^2}{c}}}{4 + \dfrac{H}{30}}$ which is a little too strong for lateral systems; but this will be a good fault, as it will add a little stiffness to the bridge. The total area of each channel is equal to sum of the area required to resist bending and that to resist direct compression.

The stress in the knee-brace AB is calculated by taking the centre of moments at C, and making the moment of its stress equal to the algebraic

sum of the moments of V and $\frac{1}{2}$ P. As before, to make these formulæ applicable to a portal make d equal to the length of the batter brace and P one-half of the sum of the pressures concentrated at the upper panel points. All lateral and vibration rods were proportioned by using the following table, which gives the allowable stresses in tons of two thousand pounds upon all rods after the initial tensions have been deducted, also the initial tensions.

DIAMETER.	Working stresses.		Initial tensions.	
	●	■	●	■
3/4 inch	2.815	3.574	0.500	0.635
13/16 "	3.261	4.157	0.625	0.794
7/8 "	3.760	4.789	0.750	0.953
15/16 "	4.303	5.481	0.875	1.111
1 "	4.890	6.230	1.000	1.270
1 1/16 "	5.525	7.038	1.125	1.429
1 1/8 "	6.205	7.904	1.250	1.588
1 3/16 "	6.931	8.830	1.275	1.746
1 1/4 "	7.704	9.814	1.500	1.905
1 5/16 "	8.523	10.856	1.625	2.064
1 3/8 "	9.387	11.956	1.750	2.223
1 7/16 "	10.298	13.117	1.875	2.381
1 1/2 "	11.253	14.335	2.000	2.540
1 9/16 "	12.256	15.611	2.125	2.699
1 5/8 "	13.304	16.947	2.250	2.858

DIAMETER.	Working stresses.		Initial tensions.	
	●	■	●	■
1 11/16 inch	14.399	18.342	2.375	3.016
1 3/4 "	15.540	19.794	2.500	3.175
1 13/16 "	16.726	21.305	2.625	3.334
1 7/8 "	17.959	22.874	2.750	3.493
1 15/16 "	19.237	24.503	2.875	3.651
2 "	20.562	26.190	3.000	3.810
2 1/16 "	21.933	27.935	3.125	3.969
2 1/8 "	23.349	29.739	3.250	4.128
2 3/16 "	24.812	31.603	3.375	4.286
2 1/4 "	26.321	33.524	3.500	4.445
2 5/16 "	28.875	35.504	3.625	4.604
2 3/8 "	29.476	37.541	3.750	4.763
2 7/16 "	31.123	39.640	3.875	4.921
2 1/2 "	32.815	41.795	4.000	5.080
2 9/16 "	34.554	44.009	4.125	5.239

The distance $G\ A = s$, Fig. 2, was assumed equal to four feet for narrow roadways, and six feet for wide ones, values for intermediate roadways being interpolated. Curved brackets are often used in bridge designing, but if any one will calculate the stress in a bracket he will no onger think of curving it for the sake of appearance.

Brackets are also used below intermediate struts both for appearance and to aid the I-beam strut to resist bending in its weakest direction, so that in proportioning it the length may be taken as the distance between the points of attachment of the brackets.

The details used for the lateral systems are shown on the accompanying plate. As can be seen there, the upper lateral strut is composed of two channel bars, either laced or latticed, the upper resting on the chord plate and riveted thereto, and the lower attached to the lower flange of the inner chord channel by a connecting plate in the form of the letter T.

The upper lateral rods are connected by bent eyes to the pins and pull against short pieces of channel which are riveted to the channels of the lateral struts.

The intermediate struts are I-beams having their webs horizontal and connected to the webs of the inner post channels by bent plates. The vibration rods are connected to the upper lateral and intermediate struts by bolts. The portal struts are connected to the webs of the inner batter brace channels by bent plates. Where vibration rods are used at the portals the webs of the portal strut channels are made parallel to the length of the batter brace, and the rods, of which there are four at each portal, are attached to pins passing through the ends of the struts. Where there are no vibration rods at the portals the flanges of the portal strut channels are made parallel to the direction of the batter braces, and the distance between the channels is increased so as to give a greater leverage to resist the bending moment on the strut. The lower lateral struts are of wood, usually 8″ × 8″, upon which rest the joists, so that the lateral rods pass beneath and attach by bent eyes to the chord pins, or, if more than one and three-quarter inches in diameter, to vertical pins dropped through the jaws, by which the lateral struts are connected to the chord pins. The lateral struts are also firmly bolted to the upper flanges of the floor beams, upon which they rest.

DESCRIPTION OF A THREE-HINGED WROUGHT-IRON ARCH AT CLERMONT, IOWA.

By James H. Cunningham, Member of the Western Society of Engineers.*

In the autumn of 1880 the town of Clermont, Ia., advertised for tenders for the construction of a highway bridge having a span of 200′, and, in accordance with a common American custom, contractors were required to prepare their own designs and to submit them to the town authorities along with their offers. The bids were opened and in due course the contract was awarded to Mr. Horace E. Horton, C. E., of Rochester, Minn., who proposed to build a wrought-iron arch so as to take advantage of the rocky banks of the stream, which were admirably adapted for good abutments for such a structure. The iron work was made in the Milwaukee Bridge Works, with which the writer was then

* Read before the Engineering Section, Royal Scottish Society of Arts, Edinburgh, November 5, 1882. Presented for discussion before the Western Society of Engineers November 20, 1883.

TABLE OF LATERAL SYSTEMS FOR IRON PRATT TRUSS

(s indicates "cross-section.")

Span in feet.	No. of Panels.	Inten. of Wind Pres.	12' Clear Roadway Pan. 1	Pan. 2	Pan. 3	Pan. 4	14' Clear Roadway Pan. 1	Pan. 2	Pan. 3	Pan. 4	Pan. 5
40	3	40	⅞'' o	¾ o			⅞ o	⅞'' o			
50	4	40	⅞'' o	1'' o			⅞ o	⅞ o			
60	5	40	1'' o	¾ o	⅞'' o		1⅛'' o	⅞'' o	1'' o		
70	5	40	2-4''-6 s [1¼'' o	2-4''-6 s [⅞'' o ⅞ o	¾'' o ⅞'' o		2-4''-6 s [1⅛ o	2-4''-6 s [1⅛'' o 1⅛'' o	¾'' o ⅞'' o		
80	5	40	2-4''-6 s [1¼'' o	2-4''-6 s [⅞'' o 1⅛'' o	¾'' o ⅞'' o		2-4''-6 s [1 3/16 o	2-4''-6 s [⅞'' o 1⅛'' o	¾'' o ⅞'' o		
90	5	40	2-4''-6 s [1⅜'' o	2-4''-6 s [1'' o 1 1/16'' o	¾'' o ⅞'' o		2-5''-7 s [1 5/16 o	2-4''-6 s [1'' o 1'' o	⅞'' o 1'' o		
100	5	40	2-5''-7 s [1½'' o	2-4''-6 s [1'' o 1 3/16'' o	⅞'' o 1⅛'' o		2-5''-7.5 s [1⅜ o	2-4''-6 s [1'' o 1¼'' o	⅞'' o 1⅛'' o		
110	6	35	2-5''-7 s [1½'' o	2-4''-6 s [1 1/16'' o 1 3/16'' o	2-4''-6 s [1⅛'' o 1⅜'' o		2-5''-7.8 s [1½ o	2-4''-6 s [1⅛'' o 1¼'' o	2-4''-6 s [1⅛'' o ⅞'' o		
120	6	35	2-5''-7.6 s [1 9/16'' o	2-4''-6 s [1⅛ o 1 3/16 o	2-4''-6 s [⅞'' o 1'' o		2-6''-8.5 s [1½'' o	2-4''-6 s [1⅛ o 1¼ o	2-4''-6 s [⅞'' o 1⅛'' o		
130	7	35	2-6''-8.5 s [1⅜'' o	2-4''-6 s [1¼'' o 1¼'' o	2-4''-6 s [1'' o 1¼'' o	¾'' o ⅞'' o	2-6''-8.8 s [1½' o	2-4''-6 s [1⅛'' o 1 5/16'' o	2-4''-6 s [1'' o 1 1/16'' o	¾'' o 1 3/16'' o	
140	7	35	2-6''-8.6 s [1 11/16'' o	2-4''-6 s [1 1/16 o 1 1/16 o	2-4''-6 s [1 1/16'' o 1 3/16'' o	15/16'' o 1⅛'' o	2-6''-9.7 s [1⅝' o	2-4''-6 s [1 3/16'' o 1⅜' o	2-4''-6 s [1' o 1⅛'' o	1⅛'' o ¾'' o	
150	8	35					2-7''-10.5 s [1 11/16' o	2-4''-6.5 s [1¼'' o 1 7/16'' o	2-4''-6 s [1¼' o 1¼'' o	2-4''-6 s [1⅜' o 1'' o	
160	8	30					2-4''-6 s [2-1⅛'' o 2-4''-6 s I 1 11/16' o	2-4''-6 s [1¼' o ⅞'' o 4''-8 s I 1 7/16' o	2-4''-6 s [1⅛'' o ⅞'' o 4''-8 s I 1¼' o	2-4''-6 s [1⅜'' o ⅞' o 4''-8 s I 1' o	
170	9	30					2-4''-6 s [2-1⅛'' o 2-4''-6 s [1 11/16'' o	2-4''-6 s [1 3/16' o ⅞'' o 4''-8 s I 1½'' o	2-4''-6 s [1 1/16' o ⅞' o 4''-8 s I 1 5/16'' o	2-4''-6 s [1 1/16'' o ⅞'' o 4''-8 s I 1⅛'' o	¾ o ¾' o
180	9	30					2-4''-6 s [2-1⅛'' o 2-4''-6 s [1¾'' o	2-4''-6 s [1⅛'' o 1 3/16'' o 4''-8 s I 1½'' o	2-4''-6 s [1 1/16' o 1⅛' o 4''-8 s I 1⅛' o	2-4''-6 s [1 1/16' o 1⅛ o 4''-8 s I 1 3/16'' o	¾' o 1 3/16'' o
190	10	30					2-4''-6 s [2-1 3/16'' o 2-4''-6 s [1¾'' o	2-4''-6 s [1⅜'' o 1 3/16'' o 4''-8 s I 1⅜'' o	2-4''-6 s [1⅛'' o 1⅛'' o 4''-8 s I 1 7/16' o	2-4''-6 s [1 1/16'' o 1 3/16'' o 4''-8 s I 1¼'' o	2-4''-6 s [⅞'' o 1⅛'' o 4''-8 s I 1 1/16'' o
200	10	30									
210	11	30									
220	11	30									
230	12	30									
240	12	30									
250	13	30									
260	13	30									
270	14	30									
280	14	30									
290	15	30									
300	15	30									

Span in feet.	16' Clear Roadway Pan. 1	Pan. 2	Pan. 3	Pan. 4	Pan. 5	Pan. 6	Pan. 7
40	⅞'' o	⅞ o					
50	1⅛'' o	⅞ o					
60	1⅛'' o	⅞ o	⅞ o				
70	2-4''-6 s [1 3/16 o	2-4''-6 s [1⅛'' o 1⅛'' o	¾ o ⅞ o				
80	2-4''-6 s [1¼'' o	2-4''-6 s [⅞ o ⅞ o	¾ o ⅞'' o				
90	2-5''-7 s [1½'' o	2-4''-6 s [1⅛'' o 1⅛'' o	¾'' o ⅞ o				
100	2-5''-8 s [1⅜'' o	2-4''-6 s [1'' o 1 3/16'' o	¾'' o ⅞'' o				
110	2-6''-8.5 s [1⅝'' o	2-4''-6 s [1 3/16'' o 1¼'' o	2-4''-6 s [1⅛'' o ⅞'' o				
120	2-6''-9 s [1 5/16'' o	2-4''-6 s [1⅛'' o 1 5/16'' o	2-4''-6 s [⅞'' o 1⅛'' o				
130	2-6''-9.5 s [1½'' o	2-4''-6 s [1⅛'' o 1½'' o	2-4''-6 s [1'' o 1 1/16'' o	¾'' o 1⅛'' o			
140	2-7''-10.5 s [1 9/16'' o	2-4''-6 s [1⅛'' o 1 5/16'' o	2-4''-6 s [1'' o 1¼'' o	¾'' o ⅞'' o			
150	2-7''-11.5 s [1⅝'' o	2-5''-7 s [1 3/16'' o 1⅜'' o	2-4''-6 s [1 1/16' o 1 1/16 o	2-4''-6 s [⅞' o 1' o			
160	2-4''-6 s [2-1⅛'' o 2-4''-6 s [1⅝'' o	2-4''-6 s [1¼' o ⅞' o 4''-8 s I 1⅜'' o	2-4''-6 s [1 1/16'' o ⅞'' o 4''-8 s I 1 3/16' o	2-4''-6 s [⅞'' o ⅞'' o 4''-8 s I 1'' o			
170	2-4''-6 s [2-1⅛' o 2-4''-6.1 s [1⅜' o	2-4''-6 s [1 5/16'' o ⅞' o 4''-8 s I 1 7/16'' o	2-4''-6 s [1⅛'' o ⅞' o 4''-8 s I 1¼'' o	2-4''-6 s [1'' o ⅞'' o 4''-8 s I 1 1/16''o	¾ o ⅞' o		
180	2-4''-6 s [2-1⅛'' o 2-4''-6 s [1 11/16'' o	2-4''-6 s [1 5/16'' o 1⅛'' o 4''-6 s I 1½'' o	2-4''-6 s [1 3/16'' o 1⅛'' o 4''-8 s I 1 5/16' o	2-4''-6 s [1'' o 1 3/16'' o 4''-8 s I 1 3/16'' o	⅞ o 1⅜ o		
190	2-4''-6 s [2-1 1/16' o 2-4''-6 s [1 11/16'' o	2-4''-6 s [1⅜'' o 1 3/16'' o 4''-8 s I 1 9/16'' o	2-4''-6 s [1⅜'' o 1⅜'' o 4''-8 s I 1⅛'' o	2-4''-6 s [1 5/16'' o 1⅜'' o 4''-8 s I 1¼'' o	2-4''-6 s [⅞'' o 1 3/16'' o 4''-8 s I 1' o		
200	2-4''-6 s [2-1⅛' o 2-4''-6 s [1⅜'' o	2-4''-6 s [1⅜'' o ⅞' o 4''-8 s I 1⅜'' o	2-4''-6 s [1⅛'' o ⅞'' o 4''-8 s I 1 1/16'' o	2-4''-6 s [1 3/16'' o ⅞'' o 4''-8 s I 1¼'' o	2-4''-6 s [⅞' o ⅞' o 4''-8 s I 1 1/16'' o		
210	2-4''-6 s [2-1⅛' o 2-4''-6 s [1 13/16'' o	2-4''-6 s [1⅛' o ⅞'' o 4''-6 s I 1⅜'' o	2-4''-6 s [1⅛'' o ⅞'' o 4''-8 s I 1½' o	2-4''-6 s [1⅛'' o ⅞ o 4''-8 s I 1 9/16'' o	2-4''-6 s [1'' o ⅞'' o 4''-8 s I 1¼' o	⅞ o 1'' o	
220	2-4''-6.2 s [2-1 5/16'' o 2-4''-6.2 s [1⅞' o	2-4''-6 s [1⅛'' o ⅞'' o 4''-8 s I 1 11/16' o	2-4''-6 s [1⅛'' o ⅞ o 4''-8 s I 1 5/16'' o	2-4''-6 s [1⅛' o ⅞' o 4''-8 s I 1⅜' o	2-4''-6 s [1'' o ⅞'' o 4''-8 s I 1 5/16'' o	⅞'' o 1'' o	
230	2-4''-6.4 s [2-1 5/16' o 2-4''-6.4 s [1⅞'' o	2-4''-6 s [1 7/16'' o ⅞'' o 4''-8 s I 1¼'' o	2-4''-6 s [1⅛'' o ⅞'' o 4''-8 s I 1 9/16'' o	2-4''-6 s [1¼'' o ⅞ o 4''-8 s I 1 7/16'' o	2-4''-6 s [1'' o ⅞' o 4''-8 s I 1¼'' o	2-4''-6 s [⅞'' o ⅞'' o 4''-8 s I 1⅛'' o	
240	2-4''-6.6 s [2-1⅞'' o 2-4''-6.6 s [1 13/16' o	2-4''-6 s [1 7/16'' o 1⅜'' o 4''-6 s I 1 13/16'' o	2-4''-6 s [1 3/16' o 1⅜'' o 4''-8 s I 1⅝' o	2-4''-6 s [1 3/16'' o 1⅜'' o 4''-8 s I 1½'' o	2-4''-6 s [1 1/16'' o 1⅜'' o 4''-8 s I 1 5/16' o	2-4''-6 s [⅞' o 1⅜'' o 4''-8 s I 1⅛'' o	
250	2-4''-6.7 s [2-1 1/16 o 2-4''-6.7 s [2'' o	2-4''-6 s [1 7/16'' o 1⅜'' o 4''-8 s I 1 11/16' o	2-4''-6 s [1⅜'' o 1⅜'' o 4''-8 s I 1 11/16' o	2-4''-6 s [1¾'' o 1⅜'' o 4''-8 s I 1 9/16''o	2-4''-6 s [1¼'' o 1⅜'' o 4''-8 s I 1⅝'' o	2-4''-6 s [1'' o 1⅜' o 4''-8 s I 1¼'' o	⅞'' o 1 1/16' o
260	2-5''-7 s [2-1½'' o 2-5''-7 s [2 1/16' o	2-4''-6 s [1½ o 1⅜' o 4''-8 s I 1⅞'' o	2-4''-6 s [1⅜'' o 1⅜' o 4''-8 s I 1⅜'' o	2-4''-6 s [1⅛' o 1⅜'' o 4''-8 s I 1 9/16'' o	2-4''-6 s [1¼'' o 1⅜'' o 4''-8 s I 1 7/16'' o	2-4''-6 s [1'' o 1⅜' o 4''-8 s I 1¼'' o	¾'' o 1⅝'' o
270							
280							
290							
300							

Span in feet.	18' Clear Roadway Pan. 1	Pan. 2	Pan. 3	Pan. 4	Pan. 5	Pan. 6	Pan. 7	Pan. 8
40	⅞'' o	⅞ o						
50	1⅛'' o	⅞ o						
60	1⅛'' o	⅞ o	⅞ o					
70	2-4''-6 s [1'' o	2-4''-6 s [1⅛'' o 1⅛'' o	¾ o ⅞ o					
80	2-4''-6.5 s [1¼'' o	2-4''-6 s [⅞'' o ⅞'' o	¾ o ⅞ o					
90	2-5''-7.2 s [1½'' o	2-4''-6 s [1⅛'' o 1⅛'' o	¾ o ⅞ o					
100	2-6''-8.5 s [1 5/16'' o	2-4''-6 s [1 o 1 3/16'' o	¾'' o ⅞'' o					
110	2-6''-9.5 s [1½'' o	2-4''-6 s [1 3/16'' o 1 5/16'' o	2-4''-6 s [1⅛'' o 1⅛'' o					
120	2-7''-10.5 s [1¼'' o	2-4''-6 s [1⅛ o 1¼'' o	2-4''-6 s [1⅛'' o ¾ o					
130	2-7''-10.5 s [1 7/16'' o	2-5''-7 s [1¼'' o 1¼'' o	2-4''-6 s [1⅜' o 1'' o	¾ o ¾'' o				
140	2-7''-11.5 s [1½' o	2-6''-7 s [1¼' o 1 5/16'' o	2-4''-6 s [1'' o 1 1/16'' o	1'' o 1⅛'' o				
150	2-8''-12.5 s [1 9/16'' o	2-5''-7 s [1 3/16'' o 1⅜'' o	2-4''-6 s [1 1/16'' o 1 3/16'' o	2-4''-6 s [¾' o 1⅜'' o				
160	2-4''-6 s [2-1¼' o 2-4''-6 s [1 9/16'' o	2-4''-6 s [1½' o ⅞' o 4''-8 s I 1⅜'' o	2-4''-6 s [1 1/16'' o ⅞'' o 4''-8 s I 1 1/16'' o	2-4''-6 s [⅞' o ⅞ o 4''-8 s I 1⅜' o				
170	2-4''-6.8 s [2-1¼'' o 2-4''-6.8 s [1 9/16'' o	2-4''-6 s [1¼' o ⅞'' o 4''-8 s I 1⅜'' o	2-4''-6 s [1¼' o ⅞'' o 4''-8 s I 1 1/16'' o	2-4''-6 s [1⅜' o ⅞ o 4''-8 s I 1' o	1⅛ o 1⅛ o			
180	2-4''-6.6 s [2-1¼'' o 2-4''-6.5 s [1⅜'' o	2-4''-6 s [1 5/16'' o 1⅛'' o 4''-8 s I 1 5/16'' o	2-4''-6 s [1 1/16'' o 1⅜'' o 4''-8 s I 1¼'' o	2-4''-6 s [1'' o 1⅜ o 4''-8 s I 1 5/16'' o	⅞ o ⅞ o			
190	2-4''-6.7 s [2-1 3/16'' o 2-4''-6.7 s [1⅜' o	2-4''-6 s [1 3/16'' o 1⅜'' o 4''-8 s I 1½'' o	2-4''-6 s [1 3/16'' o 1⅜'' o 4''-8 s I 1 5/16''o	2-4''-6 s [1'' o 1 3/16'' o 4''-8 s I 1¼'' o	2-4''-6 s [⅞'' o 1⅛'' o 4''-8 s I 1' o			
200	2-4''-6.9 s [2-1¼' o 2-4''-6.9 s [1¼'' o	2-4''-6 s [1⅜'' o ⅞'' o 4''-8 s I 1 9/16'' o	2-4''-6 s [1¼'' o ⅞'' o 4''-8 s I 1⅜'' o	2-4''-6 s [1 5/16'' o ⅞'' o 4''-8 s I 1 1/16'' o	2-4''-6 s [⅞'' o ⅞'' o 4''-8 s I 1'' o			
210	2-5''-7 s [2-1¼ o 2-5''-7 s [1¼'' o	2-4''-6 s [1¼ o ⅞ o 4''-8 s I 1 7/16 o	2-4''-6 s [1¼'' o ⅞' o 4''-8 s I 1 7/16 o	2-4''-6 s [1¼'' o ⅞' o 4''-8 s I 1¼' o	2-4''-6 s [1'' o ⅞' o 4''-8 s I 1¼ o	⅞ o 1⅜ o		
220	2-5''-7 s [2-1 5/16' o 2-5''-7 s [1 11/16'' o	2-4''-6 s [1¼' o ⅞'' o 4''-8 s I 1⅜'' o	2-4''-6 s [1¼'' o ⅞'' o 4''-8 s I 1½' o	2-4''-6 s [1¼'' o ⅞' o 4''-8 s I 1 5/16 o	2-4''-6 s [1'' o ⅞'' o 4''-8 s I 1⅛ o	¾ o 1 o		
230	2-5''-7 s [2-1 5/16 o 2-5''-7 s [1¼ o	2-4''-6 s [1¼'' o ⅞'' o 4''-8 s I 1 11/16'' o	2-4''-6 s [1⅛'' o ⅞'' o 4''-8 s I 1 9/16'' o	2-4''-6 s [1⅛' o ⅞ o 4''-8 s I 1⅜'' o	2-4''-6 s [1'' o ⅞'' o 4''-8 s I 1¼'' o	2-4''-6 s [⅞'' o ⅞'' o 4''-8 s I 1 1/16' o		
240	2-5''-7 s [2-1⅜'' o 2-5''-7 s [1⅞ o	2-4''-6.4 s [1 7/16 o 1⅜'' o 4''-8 s I 1⅜'' o	2-4''-6 s [1 5/16' o 1⅜''o 4''-8 s I 1 9/16'' o	2-4''-6 s [1 3/16'' o 1⅜'' o 4''-8 s I 1 5/16'' o	2-4''-6 s [1 1/16 o 1⅜'' o 4''-8 s I 1¼ o	2-4''-6 s [⅞' o 1⅜' o 4''-8 s I 1¼'' o		
250	2-5''-7 s [2-1 7/16' o 2-5''-7 s [1 13/16' o	2-4''-6.4 s [1 7/16'' o 1⅜'' o 4''-8 s I 1 11/16'' o	2-4''-6 s [1⅜'' o 1⅜'' o 4''-8 s I 1⅝'' o	2-4''-6 s [1 1/16'' o 1⅜'' o 4''-8 s I 1½'' o	2-4''-6 s [1¼' o 1⅜' o 4''-8 s I 1 5/16'' o	2-4''-6 s [1'' o 1⅜' o 4''-8 s I 1 1/16' o	⅞ o 1 1/16 o	
260	2-5''-7 s [2-1½'' o 2-5''-7 s [2'' o	2-4''-6.8 s [1 7/16' o 1⅜' o 4''-8 s I 1 13/16'' o	2-4''-6 s [1¼' o 1⅜'' o 4''-8 s I 1 11/16'' o	2-4''-6 s [1¼'' o 1⅜'' o 4''-8 s I 1½'' o	2-4''-6 s [1¼' o 1⅜'' o 4''-8 s I 1⅜'' o	2-4''-6 [1'' o 1⅜ o 4''-8 s I 1¼' o	¾ o 1 1/16 o	
270	2-5''-7.3 s [2-1½'' o 2-5''-7.3 s [2'' o	2-4''-6.8 s [1½' o 1⅜' o 4''-8 s I 1⅞' o	2-4''-6 s [1⅜'' o 1⅜ o 4''-8 s I 1¼' o	2-4''-6 s [1¼'' o 1⅜'' o 4''-8 s I 1 9/16'' o	2-4''-6 s [1¼'' o 1⅜'' o 4''-8 s I 1 7/16'' o	2-4''-6 s [1'' o 1⅜ o 4''-8 s I 1 5/16 o	2-4''-6 s [⅞'' o 1⅜ o 4''-8 s I 1¼ o	
280	2-5''-7.6 s [2-1 9/16' o 2-5''-7.6 s [2 1/16' o	2-4''-6.8 s [1½'' o 1⅜'' o 4''-8 s I 1 13/16' o	2-4''-6 s [1½'' o 1⅜'' o 4''-8 s I 1 13/16'' o	2-4''-6 s [1½'' o 1⅜''o 4''-8 s I 1⅝'' o	2-4''-6 s [1¼'' o 1⅜'' o 4''-8 s I 1½' o	2-4''-6 s [1'' o 1⅜'' o 4''-8 s I 1 5/16'' o	2-4''-6 s [⅞'' o 1⅜' o 4''-8 s I 1 3/16'' o	
290	2-5''-7.9 s [2-1⅞'' o 2-5''-7.9 s [2 1/16'' o	2-4''-6.8 s [1½' o 1⅜' o 4''-8 s I 1 13/16' o	2-4''-6 s [1⅜'' o 1⅜'' o 4''-8 s I 1 13/16'' o	2-4''-6 s [1½ o 1⅜'' o 4''-8 s I 1 11/16' o	2-4''-6 s [1¼'' o 1⅜ o 4''-8 s I 1 9/16' o	2-4''-6 [1 1/16 o 1⅜ o 4''-8 s I 1 7/16'' o	2-4''-6 s [1⅜'' o 1⅜'' o 4''-8 s I 1¼'' o	¾ o 1¼ o
300	2-5''-8.2 s [2-1⅞'' o 2-5''-8 s [2⅜'' o	2-4''-6.8 s [1½'' o 1⅜'' o 4''-8 s I 2 o	2-4''-6 s [1½'' o 1⅜'' o 4''-8 s I 1¾ o	2-4''-6 s [1½'' o 1⅜' o 4''-8 s I 1½ o	2-4''-6 s [1¼'' o 1⅜'' o 4''-8 s I 1 9/16 o	2-4''-6 s [1 1/16 o 1⅜ o 4''-8 s I 1 5/16 o	2-4''-6 s [1'' o 1⅜ o 1-8 s I 1 5/16 o	¾'' o 1¼ o

Span in feet.	Pan. 1	Pan. 2	Pan. 3
40	⅞'' o	⅞ o	
50	1⅛'' o	⅞ o	
60	1⅜'' o	⅞ o	¾ o
70	2-4''-6 s [1'' o	2-4''-6 s [1⅛'' o 1⅛'' o	¾'' o ⅞'' o
80	2-5''-7 s [1¼'' o	2-4''-6 s [⅞'' o ⅞'' o	¾'' o ⅞'' o
90	2-5''-8 s [1⅜ o	2-4''-6 s [1⅛'' o 1⅛'' o	¾'' o ⅞'' o
100	2-6''-9 s [1⅜ o	2-4''-6 s [1'' o 1'' o	¾'' o ⅞'' o
110	2-7''-10.5 s [1 5/16 o	2-4''-6 s [1⅛'' o 1 5/16'' o	2-4''-6 s [1⅛'' o 1⅛'' o
120	2-7''-10.5 s [1⅜'' o	2-4''-6 s [1⅛'' o 1⅜'' o	2-4''-6 s [⅞'' o ⅞'' o
130	2-7''-11.2 s [1 7/16'' o	2-5''-7 s [1 3/16'' o 1 3/16'' o	2-4''-6 s [1⅛'' o 1'' o
140	2-8''-12.5 s [1 7/16'' o	2-6''-7 s [1⅛'' o 1 5/16'' o	2-4''-6 s [1'' o 1 1/16'' o
150	2-8''-12.8 s [1 9/16'' o	2-5''-7 s [1 3/16'' o 1⅜'' o	2-4''-6 s [1'' o 1⅛'' o
160	2-4''-6.5 s [2-1 3/16'' o 2-4''-6.5 s [1 9/16'' o	2-4''-6 s [1⅛'' o ⅞'' o 5''-10 s I 1⅞'' o	2-4''-6 s [1 3/16'' o ⅞'' o 5-10 s I 1⅛ o
170	2-5''-7 s [2-1 3/16'' o 2-5''-7 s [1 9/16'' o	2-4''-6 s [1⅛'' o ⅞'' o 4''-8 s I 1⅜'' o	2-4''-6 s [1⅛'' o ⅞'' o 4''-8 s I 1 3/16'' o
180	2-5''-7 s [2-1¼'' o 2-5''-7 s [1⅜' o	2-4''-6.8 s [1 5/16'' o 1⅛' o 4''-8 s I 1 7/16'' o	2-4''-6 s [1 5/16'' o 1⅛'' o 4'-8 s I 1⅛'' o
190	2-5''-7 s [2-1 3/16'' o 2-5''-7 s [1⅜'' o	2-4''-6.8 s [1⅜'' o 1⅜'' o 4''-8 s I 1½'' o	2-4''-6 s [1⅜'' o 1⅛'' o 4'-8 s I 1⅝'' o
200	2-5''-7.2 s [2-1¼'' o 2-5''-7.9 s [1 11/16'' o	2-4''-6.3 s [1⅜'' o ⅞'' o 4''-8 s I 1½'' o	2-4''-6 s [1 3/16'' o ⅞' o 4-8 s I 1⅜'' o
210	2-5''-7.3 s [2-1 3/16'' o 2-5''-7.3 s [1¼'' o	2-5''-7 s [1⅛'' o ⅞'' o 4''-8 s I 1 9/16'' o	2-4''-6 s [1½' o ⅞' o 4-8 s I 1 7/16'' o
220	2-5''-7.4 s [2-1¼'' o 2-5''-7.4 s [1 13/16'' o	2-5''-7 s [1⅛' o ⅞'' o 4''-8 s I 1⅜'' o	2-4''-6 s [1½'' o ⅞'' o 4''-8 s I 1 7/16' o
230	2-5''-7.1 s [2-1⅜'' o 2-5''-7.4 s [1 13/16'' o	2-5''-7 s [1⅜'' o ⅞'' o 4''-8 s I 1 11/16'' o	2-4''-6 s [1⅛'' o ⅞'' o 4-8 s I 1½'' o
240	2-5''-7.7 s [2-1 7/16'' o 2-5''-7.7 s [1¾'' o	2-5''-7 s [1 3/16'' o 1⅜'' o 4''-8 s I 1⅜'' o	2-4''-6.3 s [1 5/16'' o 1⅜'' o 4''-8 s I 1 5/16'' o
250	2-5''-7.9 s [2-1½'' o 2-5''-7.9 s [1⅝'' o	2-5''-7 s [1 7/16'' o 1⅜'' o 4''-8 s I 1⅛'' o	2-4''-6.3 s [1 9/16'' o 1⅜'' o 4''-8 s I 1⅜'' o
260	2-5''-7.9 s [2-1½'' o 2-5''-7.9 s [1 13/16'' o	2-5''-7 s [1 7/16'' o 1⅜'' o 4''-8 s I 1 13/16'' o	2-5''-7 s [1 9/16'' o 1⅜' o 4'-8 s I 1 11/16'' o
270	2-5''-8 s [2-1½'' o 2-5''-8'' o 2'' o	2-5''-7 s [1¼'' o 1⅜'' o 4''-8 s I 1⅞'' o	2-5''-7 s [1¼'' o 1⅜' o 4'-8 s I 1 11/16'' o
280	2-5''-8.2 s [2-1 9/16'' o 2-5''-8.2 s [2 1/16' o	2-5''-7 s [1½'' o 1⅜'' o 4''-8 s I 1⅞'' o	2-5''-7 s [1½'' o 1⅜'' o 4''-8 s I 1¾'' o
290	2-5''-8.6 s [2-5''-8.5 s [2-1⅝'' o 2 1/16'' o	2-5''-7 s [1½'' o 4''-8 s I 1⅜' o 1 13/16'' o	2-5''-7 s [1⅜'' o 4'-8 s I 1⅜'' o 1 11/16'' o
300	2-6''-8.5 s [2-1⅝'' o 2-6''-8.5 s [2⅜' o	2-5''-7 s [1½' o 1⅜'' o 4''-8 s I 2'' o	2-5''-7 s [1⅜'' o 1⅜'' o 4''-8 s I 1 13/16'' o

PRATT TRUSS HIGHWAY BRIDGES.

don.")

20′ Clear Roadway.

Pan. 1	Pan. 2	Pan. 3	Pan. 4	Pan. 5	Pan. 6	Pan. 7	Pan. 8	Span in feet.
[illegible]″ o	[illegible] o							40
[illegible] o	[illegible] o							50
[illegible]″ o	[illegible]″ o	[illegible] o						60
2-4″-6 s[1″ o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o						70
2-5″-7 s[1[illegible] o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o						80
2-5″-6 s[1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o						90
2-6″-9 s[1[illegible]″ o	2-4″-6 s[1″ o 1″ o	[illegible]″ o [illegible]″ o						100
2-7″-10.5 s[1[illegible]″ o	2-4″-6 s[1[illegible]″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o						110
2-7″-10.5 s[1[illegible]″ o	2-4″-6 s[1[illegible]″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o						120
2-7″-11.2 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o 1″ o	[illegible]″ o [illegible]″ o					130
2-8″-12.5 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o 1[illegible]″ o	2-4″-6 s[1″ o 1[illegible]″ o	[illegible]″ o [illegible]″ o					140
2-8″-12.8 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o 1[illegible]″ o	2-4″-6 s[1″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o					150
2-4″-6.5 s[2-1[illegible]″ o 2-4″-6.5 s[1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I [illegible]″ o					160
2-5″-7 s[2-1[illegible]″ o 2-5″-7 s[1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1″ o	[illegible]″ o [illegible]″ o				170
2-5″-7 s[2-1[illegible]″ o 2-5″-7 s[1[illegible]″ o	2-4″-6.8 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	[illegible]″ o [illegible]″ o				180
2-5″-7 s[2-1[illegible]″ o 2-5″-7 s[1[illegible]″ o	2-4″-6.3 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I [illegible]″ o				190
2-5″-7.2 s[2-1[illegible]″ o 2-5″-7.2 s[1[illegible]″ o	2-4″-6.3 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1″ o				200
2-5″-7.3 s[2-1[illegible]″ o 2-5″-7.3 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	[illegible]″ o [illegible]″ o			210
2-5″-7.4 s[2-1[illegible]″ o 2-5″-7.4 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	[illegible]″ o [illegible]″ o			220
2-5″-7.4 s[2-1[illegible]″ o 2-5″-7.4 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o			230
2-5″-7.7 s[2-1[illegible]″ o 2-5″-7.7 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6.8 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o			240
2-5″-7.9 s[2-1[illegible]″ o 2-5″-7.9 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6.3 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	[illegible]″ o 1″ o		250
2-5″-7.9 s[2-1[illegible]″ o 2-5″-7.9 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	[illegible]″ o 1[illegible]″ o		260
2-5″-8 s[2-1[illegible]″ o 2-5″-8″ o 2″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o		270
2-5″-8.2 s[2-1[illegible]″ o 2-5″-8.2 s[2[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o		280
2-5″-8.5 s[2-5″-8.5 s[2-1[illegible]″ o 2[illegible]″ o	2-5″-7 s[1[illegible]″ o 4″-8 s I [illegible]″ o 1[illegible]″ o	2-5″-7 s[1[illegible]″ o 4″-8 s I [illegible]″ o 1[illegible]″ o	2-4″-6 s[1[illegible]″ o 4″-6 s I [illegible]″ o 1[illegible]″ o	2-4″-6 s[1[illegible]″ o 4″-6 s I [illegible]″ o 1[illegible]″ o	2-4″-6 s[1[illegible]″ o 4″-8 s I [illegible]″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o 4″-8 s I [illegible]″ o 1[illegible]″ o	[illegible]″ o 1[illegible]″ o	290
2-6″-8.5 s[2-1[illegible]″ o 2-6″-8.5 s[2[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 2″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-6 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	[illegible]″ o 1[illegible]″ o	300

22′ Clear Roadway.

Pan. 1	Pan. 2	Pan. 3	Pan. 4	Pan. 5	Pan. 6	Pan. 7	Pan. 8	Span in feet.
[illegible]″ o	[illegible]″ o							40
[illegible]″ o	[illegible]″ o							50
[illegible]″ o	[illegible] o	[illegible]″ o						60
2-4″-6.8 s[1 o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o						70
2-5″-7 s[1[illegible] o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o						80
2-6″-8.5 s[1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o						90
2-6″-9.5 s[1[illegible]″ o	2-4″-6 s[1″ o 1″ o	[illegible]″ o [illegible]″ o						100
2-7″-10.5 s[1[illegible]″ o	2-4″-6 s[1″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o						110
2-7″-11 s[1[illegible]″ o	2-4″-6 s[1[illegible]″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o						120
2-8″-12.5 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o					130
2-8″-12.7 s[1[illegible]″ o	2-6″-7 s[1[illegible]″ o 1[illegible]″ o	2-4″-6 s[1″ o 1″ o	[illegible]″ o [illegible]″ o					140
2-8″-13.1 s[1[illegible]″ o	2-6″-7 s[1[illegible]″ o 1[illegible]″ o	2-5″-7 s[1″ o 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o					150
2-5″-7 s[2-1[illegible]″ o 2-5″-7 s[1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I [illegible]″ o					160
2-5″-7 s[2-1[illegible]″ o 2-5″-7 s[1[illegible]″ o	2-4″-6.2 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I 1″ o	[illegible]″ o [illegible]″ o				170
2-5″-7 s[2-1[illegible]″ o 2-5″-7 s[1[illegible]″ o	2-4″-6.8 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible] o	2-4″-6 s[1[illegible]″ o [illegible]″ o 4″-8 s I 1[illegible]″ o	2-4″-6 s[1 o [illegible]″ o 4″-8 s I 1[illegible]″ o	[illegible]″ o [illegible]″ o				180
2-5″-7.4 s[2-1[illegible]″ o 2-5″-7.4 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I [illegible]″ o				190
2-5″-7.5 s[2-1[illegible]″ o 2-5″-7.5 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-8 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I 1″ o				200
2-5″-8 s[2-1[illegible]″ o 2-5″-8 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6.5 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	[illegible]″ o [illegible]″ o			210
2-5″-8 s[2-1[illegible]″ o 2-5″-8 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6.8 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	[illegible]″ o [illegible]″ o			220
2-5″-6.3 s[2-1[illegible]″ o 2-6″-6.3 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6.8 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I 1″ o			230
2-5″-8.3 s[2-1[illegible]″ o 2-5″-8.3 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1 o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o			240
2-6″-8.5 s[2-1[illegible]″ o 2-6″-8.5 s[1[illegible]″ o	2-5″-7.1 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6.5 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	[illegible]″ o 1″ o		250
2-8″-8.5 s[2-1[illegible]″ o 2-6″-8.5 s[1[illegible]″ o	2-5″-7.1 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-5″-7 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6.0 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1[illegible]″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	2-4″-6 s[1″ o [illegible]″ o 5″-10 s I 1[illegible]″ o	[illegible]″ o 1″ o		260
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24′ Clear Roadway.

Pan. 1	Pan. 2	Pan. 3	Pan. 4	Pan. 5	Pan. 6	Pan. 7	Pan. 8	Span in feet.
[illegible]″ o	[illegible] o							40
[illegible]″ o	[illegible] o							50
[illegible]″ o	[illegible] o	[illegible]″ o						60
2-5″-7 s[1″ o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o						70
2-5″-8 s[1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible] o	[illegible]″ o [illegible]″ o						80
2-6″-9 s[1[illegible]″ o	2-4″-6 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible]″ o						90
2-7″-10.5 s[1[illegible]″ o	2-4″-6 s[1″ o 1″ o	[illegible]″ o [illegible]″ o						100
2-7″-10.5 s[1[illegible]″ o	2-4″-6.3 s[1″ o 1″ o	2-4″-6 s[[illegible]″ o [illegible]″ o						110
2-7″-11.4 s[1[illegible]″ o	2-5″-7 s[1[illegible]″ o 1[illegible]″ o	2-4″-8 s[[illegible]″ o [illegible]″ o						120
2-8″-12.5 s[1[illegible]″ o	2-5″-7.3 s[1[illegible]″ o 1[illegible]″ o	2-4″-6.5 s[[illegible]″ o [illegible]″ o	[illegible]″ o [illegible] o					130
2-8″-13 s[1[illegible]″ o	2-5″-7.5 s[1[illegible]″ o 1[illegible]″ o	2-4″-6.5 s[[illegible]″ o 1″ o	[illegible]″ o [illegible]″ o					140
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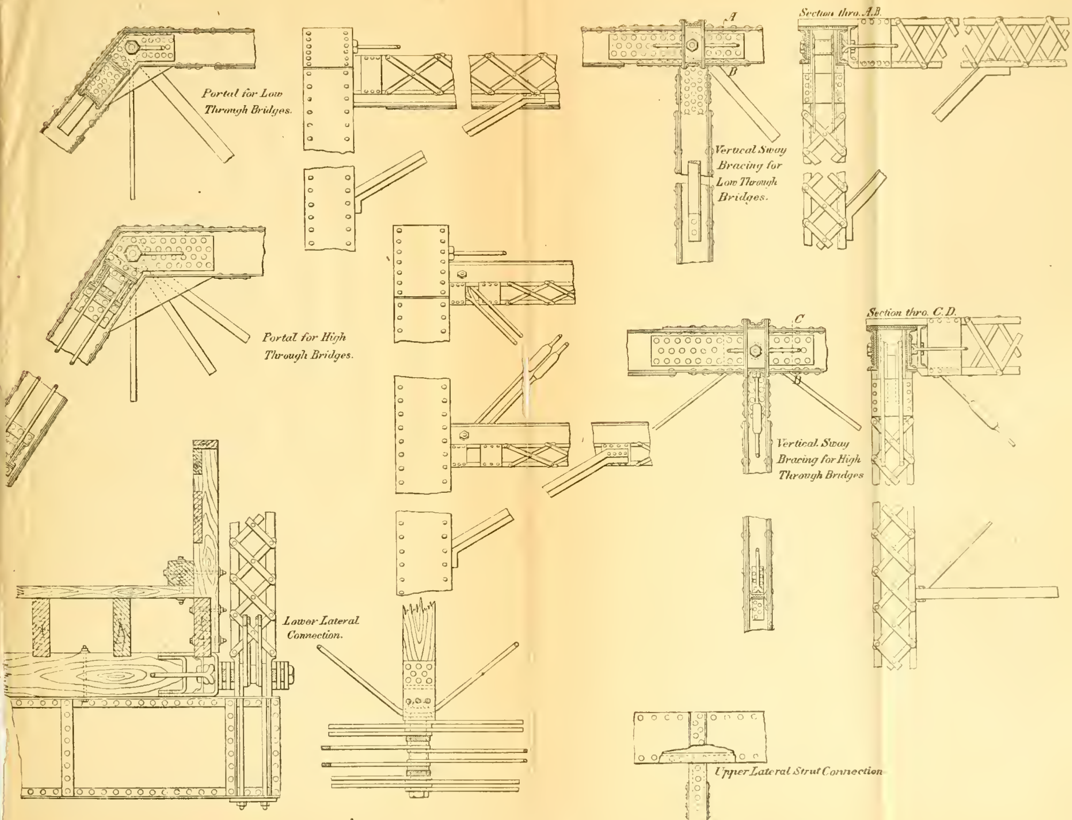


DETAILS FOR LATERAL SYSTEMS OF IRON PRATT TRUSS HIGHWAY BRIDGES

connected, and with Mr. Horton's permission he is thus able to give the the following description of the bridge :

The roadway is carried between two wrought-iron braced arches, which are hinged at the centre or crown, and also at the abutments. Wrought-iron shoes made of plates and angles rest in the masonry, and the ends of the trusses bear on pins $4\frac{1}{8}$ in. diameter, which are carried in these shoes. The centre joints are also formed by pins on which the two halves of the arch bear. The introduction of these hinges or joints into a braced arch is a well-known method of securing simplicity in the stresses and getting rid of temperature strains. In structures of this kind the stresses caused by loads can be calculated as easily and accurately as in any common truss, and changes of temperature may alter the position of the crown without producing strains in the arched ribs. The roof of the terminus of the Berlin & Anhalt Railway in Berlin is a specimen of a three-hinged arch. The main rafters are braced ribs 205′ span and having 50′ rise, hinged by pin joints both at the springings and at the crown (see *The Engineer*, 12th Nov., 1880). The Clermont bridge only differs from other structures of this type in the peculiar form given to the trusses. They are made more like Warren girders than arches. *Two* advantages are obtained by adopting this somewhat unusual form. In the *first place*, great lateral stiffness is secured, because it is possible to use better wind bracing than could be put in an ordinary arch. It will be seen from the detail drawing that there are complete top and bottom lateral systems, also strong portal bracing, and these could hardly be so perfect if the ordinary form of arched rib was adhered to. *Secondly*, this arrangement of truss admits of the use of very long panels, and this simplifies the whole construction and at the same time tends to secure economy both of material and workmanship.

But although the trusses are of an unusual type the way in which they have been worked out by Mr. Horton as to the general arrangement of the parts and the details of the connections is a good example of the American method of treating trusses of all kinds. This general form is shown on Fig. 2, from which it will be seen that they are divided into 5 bays or panels each 40′ long.* Vertical ties and struts are introduced for convenience in arranging the details, but they are only subsidiary numbers and not essential parts. Those at the lower panel points, the struts, merely stiffen the long portions of the top chords and the others, the ties, carry the loads on the floor beams to the upper panel points. By adopting these long panels the trusses are made to consist of comparatively few members and none are introduced which are not absolutely required, or which cause ambiguity in the stresses. These can therefore be easily and accurately calculated, and as has been stated are not affected by temperature owing to the hinge joints introduced at the centre of the top chord and at the abutments. All the principal connections are made by pins except two. The two sections of top chord on each side of the centre are riveted together so as to form one piece from the top of the end post to the centre joint of the arch, but the braces *op*, *pg* and *ts*, *st* (Fig. 2) are connected to these long sections by pins. Many American

* The diagrams referred to by Mr. Cunningham have been lost, excepting those which are printed herewith.—H. G. P.

engineers endeavor to arrange their trusses somewhat in the way just described. They adopt long panels and a simple form of truss consisting of the fewest possible number of parts. They thus get rid of all uncertainty as to the stresses and obtain great economy in material without sacrificing the strength or permanence of the structure. Further, by adopting the pin joint, the work, both of construction in the shop and erection in the field, is facilitated and the stresses are made to act directly along the mean fibres of the various members.

The stresses on the Clermont trusses may be determined in various ways. The following method was used by the writer to verify, for his own satisfaction, Mr. Horton's calculations: The weight of the structure itself, or what is called the dead load, was assumed to be uniformly distributed and applied at the panel points in equal portions. The moving or live load was treated in the same way, but was supposed to move slowly along the truss from left to right. The stresses caused by these loads, acting separately, were first determined, and then the values obtained were added together, their algebraic sums being the maximum stresses. The method of calculation is essentially graphic, but the first step always is to find the end reactions, both vertical and horizontal, by taking moments round the abutments and centre point. Having found these reactions for the fully distributed dead load, polygons (Fig. 3) were drawn, giving the stresses on the various members of the truss, and these stresses were then marked on the skeleton diagram (Fig. 2). The maximum stresses in all those members which are most strained by a fully distributed load, were then written down at once for

$$\frac{\text{maximum stress}}{\text{dead load stress}} = \frac{\text{dead} + \text{live load.}}{\text{dead load.}}$$

These members are the top chord sections and end posts.

To find the maximum stress caused on the web members by the live load, a set of polygons (Fig. 4) was drawn, giving the stresses which act on every member of the truss when the proper panel load (*ab*, Fig. 2) is applied at the panel point nearest to one abutment—that is, in this case, at the top of one of the end posts. These stresses were also marked on the skeleton diagram, and may here be called for convenience "base stresses," as they were the basis of further calculations. The effect of a load applied at the first point being now known, a process of addition to the several base stresses gave the effects produced by applying loads at the second, third and remaining panel points. This may be more clearly explained by an example. Take, for instance, the brace *q j*, Fig. 2. The live load *a b* causes a stress of 1,980 pounds on this member. This has been called the base stress. The load *l k* will cause twice this stress, the load *b c* three times, and the load *k j* four times. If, therefore, all these loads are applied simultaneously, the stress along *q j* will be the base multiplied by $1 + 2 + 3 + 4 = 10$, and it can be shown that this is the maximum tensile stress which can act along this member. The maximum stresses on the other web members, except *t u*, were found by a similar process. That on *t u* could not be found in this way, because an unknown part of the shearing stress acts along *u h*. But by a slight change in the method, both these stresses were readily determined from data furnished by the sets of polygons already drawn (Figs. 3 and 4). So far it has been assumed that the live loads *were applied one after another.*

from left to right, and the effect of thus gradually increasing the load has been considered. If, on the contrary, it is assumed that all the live loads are applied at their respective panel points, *and the effect of removing the end one is considered,* there will be no difficulty in arriving at the stresses on *t u* and *u h*. Accordingly, the stresses caused on these members by a fully distributed live load were found by multiplication from the values given by the polygons of Fig. 3, and thus the strains on *o n* and *n l* given by the polygons of Fig. 4 being the increments caused by the load *e f* were subtracted from them, the results being the stresses on the *t u* and *u h* when the truss is loaded up to *i h*. These are the maximum values of the live load stresses in these members.

It is always well to check calculations by independent methods. One or two sets of polygons were therefore drawn to verify the results obtained by the process just described. Fig. 5 is the set of polygons, giving the stresses where all the panel points are loaded, except the top of the end post at *u f*, this being, as has just been stated, the arrangement of loads which causes the greatest stresses in *t u* and *u h*.

A little consideration was also required to find the stress in *si* correctly. When the loads *a b* to *c d*, inclusive, are applied, it is 15 times the base. The addition of the load *j i* (which causes the maximum stress) reduces the compression on *r j* and therefore, also, on *s i*, and finally adds just one unit to the multiplier. The maximum stress on *s i* was accordingly found to be 16 times the base. The maximum live load stresses having been found on every member, the last step was to add them to the corresponding dead load stresses and mark the results in the strain diagram (Fig. 1).

The dead weight was estimated at 700 lbs. per lin. ft. of bridge, and this proved to be practically correct, as about 80,000 lbs. of iron and 25,000 ft. B. M. of pine were used in the work. The live load was taken at 1,400 lbs. per lin. ft., or 87½ lbs. per sup. ft. the roadway being 16′ wide. The panel length is 20′ and the panel loads were therefore 7,000 lbs. dead and 14,000 lbs. live. The material was proportioned as nearly as possible, so that the strains caused by these loads should not exceed a tension of 12,500 lbs. per sq. inch in tie bars nor a compression in posts, which was determined by the formula $\dfrac{12{,}500}{1 + \dfrac{H^2}{1800}}$; *H* being the length of the strut in terms of its shortest side. The composition and dimensions finally selected for the several members as satisfying these conditions, as well as the requirements of actual construction, are marked on the strain diagram (Fig. 1); also their sectional areas, the actual strain per inch and the value of *H*. The dimensions of the lateral bracing and pins are also marked in the strain diagram.

The limits of strain just given are greater than those usually allowed in railroad work. But 87½ lbs. per sup. ft. is an extreme load for a country highway, and as it is not probable that the bridge will ever be fully covered with such a load, the estimated maximum stresses are not likely to occur in reality, and therefore it is judicious to adopt these higher limits. In the best class of bridges tensile strains are usually limited to 10,000 lbs. per sq. inch, in members which are not liable to shocks, and in which the stresses are not always so great as estimated. Such members are bottom chords and diagonal bars near the ends of trusses. Long

bars liable to be suddenly strained are generally proportioned so that the tension shall not exceed 6,000 to 8,000 lbs. per sq. inch, and in floor beam suspenders, which are severely strained by every engine which goes across the bridge, the tension is limited to 4,000 lbs. per sq. inch.

The limit of compression is generally determined by a formula of the form given above. A variety of numerical constants are in use depending on the cross section of the strut, or whether the ends are fixed by rivets or bear on pins, and on the grade of iron to be used in the work. For the sake of comparison, and to give a graphic representation to the eye the safe comparison strains found by Mr. Horton's constants, also those found by using constants taken from the specification of a well-known railroad:

$$\text{D. J. W's sq. col. round ends } \frac{37800}{1 + \frac{H^2}{1900}} \div 4 + \frac{6\ H}{100}$$

have been plotted on a diagram, Fig. 6. Lines have also been drawn to represent the tensile strain allowed in this arch and that generally permitted in railroad work. A good deal of attention has been given during the last few years to the proper proportioning of pins, and to ascertaining (by experiments) the proper form of head for eye bars. Care is taken to design the pin and eye so that fracture will occur in the body of the bar and not in the head. To secure this, the railroad specification already referred to, requires that in pins the shearing stress shall not exceed 7,000 lbs. per inch, that the bearing pressure on the surface of the semi-intrados shall not exceed 8,000 lbs. per square inch, and that the bending strains in the extreme fibre shall not exceed 15,000 lbs. per square inch. The relations between width of bar, diameter of pin, and width of head are also specified. Pin joints proportioned in this way give satisfactory results, and continue to be popular in America. The details of the trusses are shown on the blue print and do not require much explanation. It will be seen that the members which have to resist tension only, consist of flat bars. The ends of those bars were forged in dies into large heads, which were then accurately bored to fit the pins. Those members which have to resist compression consist of rolled channel bars connected by a lattice of light $2'' \times \frac{1}{4}''$ bars. Plates are used instead of lacing for a short distance at the ends of the posts, and in part of the top chord lacing is only used on the lower side of the channels and a plate is riveted on the top. Re-enforcing plates are riveted to the webs of the channels to give proper bearing surface for the pins. The floor beams are riveted plate and angle girders, and are placed transversely across the bridge at the panel points. They are riveted to the vertical members of the truss. The floor consists of 3'' plank, and is carried on 12 pine stringers or joints, $4'' \times 14''$, which rest on the transverse floor beams. All the members were completely finished in the shop, and only a few rivets had to be driven in the field to connect them together. The bill of field riveting is as follows:

In the main trusses	56	rivets	$\frac{5}{8}''$	diameter.
vertical members	48	"	$\frac{1}{2}''$	"
floor beam connections	216	"	$\frac{1}{2}''$	"
portal	32	"	$\frac{5}{8}''$	"
whole work	352			

GRAPHIC SHEET of CLERMONT BRIDGE.

BY HORACE E. HORTON.

Span 200'. Height 30' & 20'. Panels 10 of 20'.

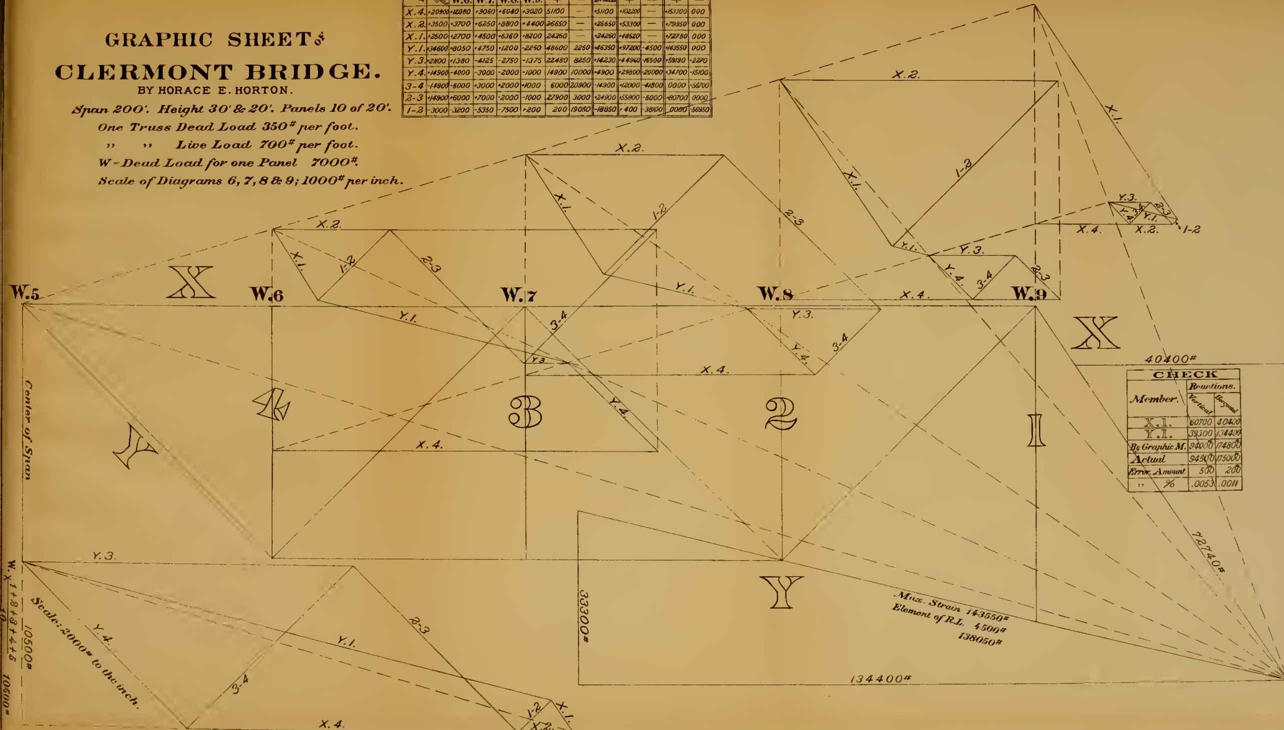
One Truss Dead Load 350# per foot.

" " Live Load 700# per foot.

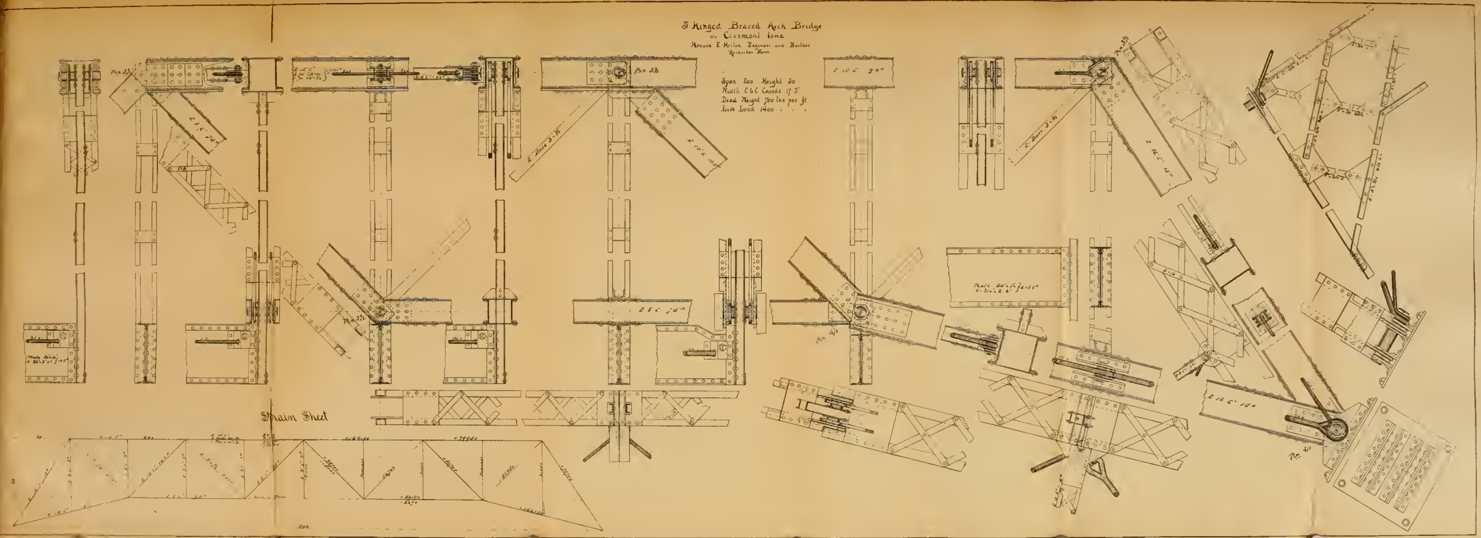
W = Dead Load for one Panel 7000#.

Scale of Diagrams 6, 7, 8 & 9; 1000# per inch.

Member	Dead Load - 7000# per Panel.								Live Load twice D.		Maximum Strains	
	[illegible]	W.6.	W.7.	W.8.	W.9.	+	—	Dead L.	+	—	+	—
X.4.	+20900	+12080	+9060	+6040	+3020	51100	—	+51100	+102200	—	+153300	000
X.2.	+3500	+3700	+6250	+8800	+4400	26650	—	+26650	+53300	—	+79950	000
X.1.	+2500	+2700	+4500	+6360	+8200	24260	—	+24260	+48520	—	+72780	000
Y.1.	+34600	+8050	+4750	+1200	-2250	48600	2250	+46350	+97200	-4500	+143550	000
Y.3.	+2100	+1380	-4125	-2750	-1375	22480	8250	+14230	+44960	-16500	+59190	-2270
Y.4.	+14900	-4000	-3000	-2000	-1000	14900	10000	+4900	+29800	-20000	+34700	-15100
3-4	-14900	-6000	+3000	+2000	+1000	6000	20900	-14900	+12000	-41800	0000	-56700
2-3	+14900	+6000	+7000	-2000	-1000	27900	3000	+24900	+55800	-6000	+80700	0000
1-2	-3000	-3200	-5350	-7500	+200	200	19050	-18850	+400	-38100	0000	-56950



CHECK		
Member.	Reactions.	
	Vertical	Horizontal
X.I.	60700	40400
Y.I.	33300	134400
By Graphic M.	94000	174800
Actual	94500	175000
Error. Amount	500	200
" %	.0053	.0011


3 Hinged Braced Arch Bridge
at Clermont Iowa
Horace E Horton Engineer and Builder
Rochester Minn
Span 200 Height 30
Width C&C Chords 17 5'
Dead Weight 700 lbs per ft
Live Load 1400 " " "
Strain Sheet

The quantities of material were (finished weight)—

Iron in floor beams	7,212	lbs.
" riveted members	65,282	"
" bars	8,266	"
" total	80,766	

Pine plank, joists, etc., 25,103 B. M.

The cost of work was as follows:

		£	s.	d.
Iron f. o. b. Milwaukee at 4½c.	$3,636.67	757	3	7½
Lumber at $14.50 per M	364.00	75	16	8
Freight	247.51	51	11	3½
Laborers at $1.75 per day	274.34	57	3	1
Foreman's time, $5 per day	100.00	20	16	8
Paint, spike, drayage, personal expenses	118.12	24	12	2
Use of tools, general expenses	107.12	22	6	4
Total cost of work	$4,845.56	£1,009	9	10
Profit	354.44	73	16	10
Price paid for work complete	$5,200.00	£1,083	6	8

In the foregoing statement of cost the dollar is taken as equivalent to 4s. 2d. Bridge material delivered in Milwaukee or Chicago cost at the time the work was executed 4½c. per pound, or £21 per English ton.

Immediately after the bridge was finished it was tested by spreading sand over the floor amounting to the full load of 1400 lbs. per foot, and then six loads of 3½ tons each were moved over the entire length of the bridge, two loads abreast, the six loads occupying only one-quarter the length of the span. A curious thing was observed while this test was being made. When the load amounted to 106 tons the deflection was 1⅛", but when the full load of 137½ tons had been placed on the floor the deflection was only ⅝". The first observation was made early in the morning and the final one about mid-day, and the increase of temperature during the forenoon actually decreased the deflection, though the load was constantly being increased.

After all it may be asked, "Is this arch really cheaper than an ordinary beam truss?" "Could not an ordinary beam truss have been made as strong as this arch without using any more materials?" This question can be answered to some extent without very much labor by making a rough estimate of the weight of a Warren truss. A Warren truss having five panels 40′ 0″ long and 30′ 0″ deep, with intermediate suspenders and struts, is probably as light as any other kind of trusss. In a bridge consisting of two such trusses, the floor beams and lateral systems would be much the same as in the Clermont arch, and there would be the same number of pin connections. It will not therefore be far wrong to assume that the whole difference in the weights of the material will be in the trusses. A strain sheet (Fig. 8.) has been made for such a Warren truss and sections taken for the various members, giving as nearly as possible the same strength as in the arch.

On calculating the weights from these sections (neglecting lacing and

small plates which will be much the same in both) it will be found that there are 11,262 lbs. more iron in the beam than in the arch.

In one truss	Clermont	7,035 inch feet
" "	Warren	8,711 " "
		1,676 × 2 × 3.36 lbs. = 11,262

It is therefore probable that the arch is 12 per cent. lighter than any

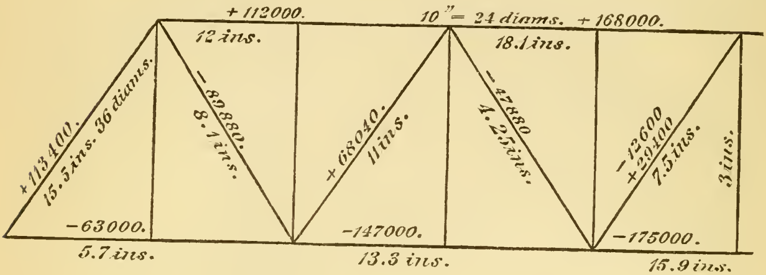


Fig. 8.

beam would be. At the rate current when the work was done this is equivalent to a saving of $506, or nearly £105.

It therefore appears that the Clermont arch is no mere eccentricity built only to comply with a theory which may not be of any practical utility, but while theory has been strictly adhered to a bridge has been produced which is both strong and cheap, and is likely to be quite satisfactory to those who regard such structures from a commercial rather than a mathematical point of view.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF ST. LOUIS.

JANUARY 30, 1884 :—The Club was called to order at 8 o'clock P. M., twenty-five members and five visitors being present and President Woodward in the chair.

The Committee on Permanent Quarters reported favoring the acceptance of the offer of the Mercantile Library, and reported that thirty-three members had already offered to take tickets.

It was moved that the committee be authorized to conclude the arrangement with the Mercantile Library for meeting there in consideration of the Club's taking forty memberships at $5 each. *Carried.*

The Treasurer submitted his annual report, with a list of delinquents.

The committee was instructed to correspond with all the delinquents and collect back dues.

Mr. Humphreys and Mr. Edward Flad were appointed to audit the Treasurer's report.

The following gentlemen were unanimously elected members: Charles L. Brown, J. B. Stone, F. A. Churchill, Wm. H. Bryan, Edward Molitor.

The following gentlemen were proposed for membership: C. V. Mersereau and Wm. Bouton by Robert McMath and J. B. Johnson, and S. Bent Russell by T. J. Whitman and M. L. Holman.

The President announced the Committee on Smoke Prevention as follows: Henry Flad, E. D. Meier and C. F. White. This committee to report next June.

The auditing committee reported that they found the Treasurer's accounts correct, and the report was accepted and filed.

The following amendments to the constitution were adopted :

Article XXIII. changed to read: Members and corresdonping members to pay an initiation fee of five (5) dollars and an annual subscription of not exceeding ten (10) dollars.

Article XXV. changed to read: Persons whose subscriptions are in arrears one year may be stricken off the list of the Association by a majority of the members present; provided that the member has had one month's notice of such delinquency.

It was moved that all members who have paid the $12 initiation and who have not received a life membership in the Public School library should be credited with $7 on the new annual dues. This was laid on the table.

Mr. Sobolewski then continued his article on "The Use and Abuse of Illuminating Gas," which was partly read at last meeting. He illustrated his remarks by a gas meter, so arranged as to show all its workings.

Mr. Garland, the inventor of the Garland gas governor, being present, was called on to explain the working of the governor and the conditions of its use.

Mr. Sobolewski's paper was discussed by Messrs. Todd, Potter, Moore and Belcher.

The subject for next meeting will be "Thermo-dynamics Applied to Compressed Air," by Professor Woodward.

[*Adjourned.*] J. B. JOHNSON, Secretary.

FEBRUARY 13, 1884 :—The Club met at 8 o'clock P. M. at the Mercantile

Library, with President Woodward in the chair. There were 25 members and four visitors present.

The Committee on Permanent Quarters reported that the arrangements with the Mercantile Library were not yet fully completed.

The following gentlemen were proposed for membership : M. P. Brazill by Carl Gayler, and H. G. Tidemann by E. D. Meier and Henry Flad.

Three members were elected, C. V. Mersereau, Wm. Bouton, and S. B. Russell.

The Treasurer read a list of delinquent members.

The President announced the death of Prof. Chas. A. Smith, at Newburyport, Mass., on the 2d inst. He had been Secretary of the Club for twelve years. Thos. J. Whitman, Frank H. Pond and M. L. Holman were appointed a committee to draft resolutions.

On motion, Messrs. Hill, Miller and Johnson were appointed a committee to examine into the affairs of the Club and levy an assessment.

The Secretary read a communication from Mr. Williams of the Chicago Club in reference to continuing the publication of their proceedings in the Association Journal.

It was moved and carried that the Club was favorable to continuing the publication with the Journal and that the Secretary inform the Chicago Club of its action.

Prof. Potter presented a petition for signatures to Congress praying for the passage of Mr. Payson's bill for the appointment of a commission on testing engineering materials.

Col. C. Slater Smith explained the origin and intent of the bill, and urged the signing of the petition.

Mr. Hill asked for information in regard to what inducement there would be for Fairbanks & Co. to bring one of their large 50-ton testing machines into the city.

Col. Flad gave his experience with a similar machine some years ago, which was adverse to the project.

The Committee on Resolutions reported as follows :

President and Members of the Engineers' Club of St. Louis :

Gentlemen—Your committee, appointed for presenting appropriate resolutions upon the death of our associate, Prof. Chas. A. Smith, beg leave to submit the following:

Resolved, That with deep sadness we enter upon our records the death, on Feb. 2, 1884, of Prof. Charles A. Smith, one of our most valued members and for nearly twelve years the Secretary of this Club.

By his untimely death in the full vigor of his age our profession is robbed of one of its most zealous and successful workers, and our Club loses a member to whom it owes a debt greater than to any other for faithful services in its behalf.

But more than all do we, his friends, and many of us his pupils, suffer the great personal loss of a beloved fellow worker and companion, whose place cannot be filled, and we extend to his family our heartfelt sympathy, and we will with them cherish the memory of his useful life as an inspiration and example.

Thos. J Whitman,
Frank H. Pond,
M. L. Holman, } Committee.

Mr. E. D. Meier said : He was literally a victim to his profession. His devotion to his work led him to neglect his own comfort and bodily needs. He believed the way to advance the profession was to work it up in all its ranks. His work has led to a great increase of intelligent appreciation of scientific principles among practical mechanics and steam engineers. He helped bridge over the chasm between theory and practice.

Col. Flad and Prof. Potter spoke in high praise of him as a gentleman and an engineer.

Prof. Woodward spoke in regard to his early life. "He was a student in the

High School at Newburyport, Mass., when I was principal of that school. I have been intimately acquainted with his youthful training and education in the Massachusetts Institute of Technology. It was at my suggestion that he came here from North Carolina, where he was engaged in railroad work. We have always been students together. He was always anxious to get to the bottom of things. His death is at once an example and a warning. He certainly was a victim of his zeal and devotion."

It was ordered that the resolutions be engrossed and forwarded to the widow of the deceased.

Prof. Woodward then discussed the mathematical basis of the use of compressed air.

A communication was received from Mr. Dyer, to the effect that the Mercantile Library would take such professional papers and periodicals as the Club might suggest.

[*Adjourned.*] J. B. JOHNSON, Secretary.

FEBRUARY 27, 1884:—The Club met at eight o'clock P. M., at the Mercantile Library, twenty-eight members and ten visitors being present.

The Committee on Assessments reported as follows :

The committee appointed to levy an assessment on the Club for current expenses for the coming year beg to report as follows :

First—That all resident members not taking the membership ticket in the Mercantile Library be assessed $4.

Second—That all resident members taking a membership in the library be assessed $8.

Third—That all members who are at present subscribers to the library be assessed $4, plus the sum necessary to continue their subscriptions to the 1st of February, 1885. These sums are submitted in the accompanying letter from the Librarian.)

Fourth—That non-resident members be assessed $3.

Respeetfully submitted.

J. W. HILL,
T. D. MILLER, Committee.
J. B. JOHNSON,

The report was adopted.

The Committee on Permanent Quarters reported that the arrangement with the Mercantile Library had been completed, and that forty memberships in the library taken by the Club would be considered a recompense for the use of a room in which to hold the meetings.

A list of periodicals taken by the library was read by the Secretary.

The following names were proposed for membership : Norman C. Bassett, by C. M. Woodward and C. W. Melcher, and H. A. Wheeler by W. B. Potter and J. B. Johnson.

Two new members were elected—M. P. Brazill and H. G. Tidemann.

An unfinished crayon drawing of the late Prof. Smith was exhibited, and a copy ordered for the Club.

The resolutions passed at the last meeting were exhibited engrossed on parchment.

It was moved that a permanent committee of three be appointed to take charge of the relations of the Club to the library, suggest engineering books and periodicals to be purchased, and bring before the Club such reports of current literature as they may deem proper. The President appointed Prof. Potter, C. Shaler Smith and D. C. Humphreys.

The Treasurer was ordered to procure a blackboard for the use of the Club.

Mr. McMath then read a paper on "Levees ; Their Relation to River Physics."

The paper was discussed by Prof. Woodward, Col. Moore, Maj. Ernst and Messrs. Sedden, Johnston, Meier, Wheeler and others.

Mr. McMath was invited to prepare a second paper on a kindred subject at his convenience.

[*Adjourned.* J. B. JOHNSON, Secretary.

MARCH 12, 1884:—The club met at 8:15 P. M., with President Woodward in the chair, there being thirty-two members and three visitors present. The minutes of the last meeting were read and approved.

Prof. Potter reported for the Library Committee that the Librarian was preparing a special catalogue of engineering books and periodicals for the use of the Club.

The Treasurer reported a list of delinquent members who had had due notification of such delinquency, and on a vote of the Club the following names were dropped from the rolls according to the constitution: Regis Chauvenet, C. W. Dwelle, Chas. E. Illsley, Wm. D. Marks and Thad. S. Smith.

The following gentlemen were elected members: H. A. Wheeler and Norman C. Bassett. The name of C. H. Sharman was proposed for membership by Robt. Moore and E. D. Meier.

The Secretary read a letter from Benezette Williams, Chairman of the Board of Managers for the JOURNAL, conveying the information that the Western Society had voted to withdraw from the Association in the matter of publishing in the associated JOURNAL.

The crayon portrait of Prof. C. A. Smith, late Secretary of the Club, drawn by Mrs. C. W. Metcher, was shown on the walls of the room, in a handsome frame, and the sum of twenty-five dollars was appropriated for the artist.

Robert Moore then read a paper on "The Separate vs. The Combined System of Sewerage," being mainly a review of a lecture delivered in Kansas City, by Mr. O. Chanute, on the sewering of that city. At the close of the reading, Mr. Chanute being present, was introduced to the Club, and replied at length to the several criticisms which had been raised against his article, and he was requested to embody his remarks in a paper to be published in connection with that of Mr. Moore.

Both gentlemen were heartily applauded in appreciation of the facts and arguments presented.

The subject was further discussed by Messrs. Meier, McMath, Stone, C. Shaler Smith, Whitman and others.

The programme for next meeting was announced.

[*Adjourned.*] J. B. JOHNSON, Secretary.

WESTERN SOCIETY OF ENGINEERS.

FEBRUARY 5, 1884 :—The 179th meeting was held at 4 P. M., President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

The following names were proposed for election as members:

George E. Palmer, Western Manager and Superintendent for the Babcock & Wilson Company, indorsed by Messrs. Benezette Williams, Edgar Williams and Charles MacRitchie ; George Remington Bramhall, Superintendent of Bridges, Department of Public Works, Chicago, indorsed by Messrs. Wright, Lotz, and Benezette Williams.

Mr. Ferdinand Hall, Assistant Engineer Chicago & Alton R. R., proposed at the 177th meeting, was elected an Associate.

Written and oral arguments on the question of withdrawal from the Association of Engineering Societies were presented by Messrs. Wright, Benezette Williams, Latimer, Morehouse, Liljencrantz, Cole, MacHarg and Fitz Simons.

It was voted that the Librarian and Secretary should decide what unbound magazines and periodicals should be bound, and have this work done.

It was farther voted that the Librarian and Mr. MacHarg be a committee authorized to design and have constructed another book-case.

At the suggestion of Mr. Cregier, it was ordered that the Committee on Portraits have the portrait of the Society's first Secretary added to the number of those previously ordered by the Society.

A paper by Prof. J. A. L. Waddell, "Lateral Systems for Iron Pratt Truss Highway Bridges," was presented by the Secretary.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

FEBRUARY 19, 1884 :—The 180th meeting was held at the Society rooms at 4 P. M., President Cregier in the chair.

In the absence of the Secretary, Mr. Liljencrantz was appointed secretary pro tem.

The minutes of the preceding meeting were read and approved.

Mr. Nichol, for the committee to whom was referred the matter of cost, etc., of publishing the JOURNAL OF ENGINEERING SOCIETIES reported that only two members of the committee had met. Mr. Wright stated that his absence from the meeting of committee was owing to a misunderstanding as to the time.

On motion of Mr. Cole, Messrs. Nichol and Wright were instructed to prepare a report upon the subject referred to the committee and present the same at this meeting. The committee not being able to agree upon the question submitted, presented a majority and minority report.

Written and oral arguments were presented by Messrs. Benezette Williams, Nichol, Liljencrantz, Green, Wright, Fitz Simons and Cole.

[*Adjourned.*] G. A. M. LILJENCRANTZ, Acting Secretary.

MARCH 4, 1884 :—The 181st meeting was held at 4 P. M., President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Upon ballot, Messrs. George E. Palmer and George Remington Bramhall were elected members.

Mr. Wright, for Topical Committee on Transportation, etc., announced a paper on Electric Motors for the next meeting.

The Secretary read a communication from Mr. Charles H. Tutton, and one from Mr. Samuel McElroy, opposing the withdrawal of the Society from the Association of Engineering Societies. The Secretary also presented a letter from the Civil Engineers' Club of St. Louis, which was ordered read and placed on file, urging the Society to retain its membership in the Association.

After a brief oral discussion, which was participated in by Messrs. Green, Benezette Williams, Adler, Greeley, Wright and MacHarg, upon motion of Mr. Greeley, it was ordered that the vote on the question of withdrawal from the Association of Engineering Societies be taken by yeas and nays and that the entire list of names be called.

The Chair appointed Messrs. Artingstall and Randolph a committee to arrange in alphabetical order the letter ballots received from members not present.

Pending the action of this committee, it was voted that Messrs. Artingstall, Cregier and Cooke be appointed to report at the next meeting upon the expediency of making some change in the order of business at regular meetings.

Upon request, the Chair was authorized to add two others to this committee, and Messrs. Fitz Simons and Green were appointed by him as additional members.

It was further voted that all topical committees should be requested to report progress at the next meeting.

Mr. Liljencrantz submitted the following, which was adopted :

WHEREAS, the printing of papers and discussions on the question of our Society's withdrawal from the "Association of Engineering Societies" was made on purpose to furnish absent members with arguments on both sides, to assist them in casting a ballot based on an intelligent opinion, and

WHEREAS, This object has been secured, through the Proceedings, which have been printed separately and sent to each member ; therefore

Be it Resolved, That none of the written or oral arguments shall be reprinted, either in the JOURNAL OF THE ASSOCIATION or in any other periodical.

The roll being called on the question of withdrawal from the Association of Engineering Societies, 37 votes were cast in the affirmative and 26 in the negative.

The Chair announced that the Society by this vote had decided to withdraw from the Association at the close of the fiscal year.

Mr. Williams, Manager for the Society in the Association, stated, in answer to inquiry, that the fiscal year would expire in November next.

The Librarian reported that he had arranged for the binding of the books ordered by the Society.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. III. 1884. Nos. 3 and 4.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

THE PUMPING PLANT AT THE BOSTON SEWERAGE WORKS.

By E. D. Leavitt, Jr., Member of the Boston Society of Civil Engineers.

[Read November 20, 1883.]

The subject will be considered under the following heads:

1st. The high-duty engines.

2d. The low-duty storm engines.

3d. The boilers and their appendages.

4th. The foundations and pump wells.

The designations "high duty" and "low duty" as applied to the engines, are the same as were used in the original advertisement for proposals; they are used here for convenience simply.

The High-Duty Engines.

These engines are of a special compound beam and fly-wheel type, designed for the service, which it is hardly necessary to say, is peculiar, both in respect to quantity, and quality of the material to be moved.

The leading considerations which governed the design were as follows:

1st. Such a distribution of the weight of the engines as should avoid concentrated pressure upon any point of the foundations.

2d. Placing the engines on the smallest practical area of foundations. These considerations obtained in consequence of the character and depth of the excavation required at the site selected for the pumping station.

3d. Great strength in the details, and combination of the parts, to render liability of a breakage a minimum.

4th. Such a proportion of journals and other wearing surfaces as would allow uninterrupted operation for extended periods, with the least possible wear.

5th. Easy accessibility of all the parts for examination, repairs, and renewals.

6th. Adaptation of the pumps, and their valves to the special duty required of them, *i. e.*, to allow the passage of rags, sticks, and other

small bodies not detained by the filth hoist, and in addition, such a construction as should admit the removal of an entire pump, or any of its parts, with ease and rapidity, and without disturbing any other prominent parts of the engine.

7th. A high degree of economy in the consumption of coal.

8th. Automatic regulation at different speeds.

The general construction of the engine consists in placing the cylinders, which are vertical and inverted, directly over the pumps, with the beam midway, or nearly so, between them, its journals being carried in the bed-plate.

The steam cylinders are supported by an entablature which is carried on eight strong columns, that are keyed and bolted to the bed-plate, while the pumps are hung underneath the same by strong brackets. They also obtain additional support from girders built into the masonry at the base of the delivery chambers, and their connection to the girders is such that as much, or as little weight as desired, can be placed upon them by means of jack-screws. These girders serve a further useful purpose in forming a track upon which the pumps can be run back from their normal position and removed if required.

The beam is made very short, being 16 feet 6 inches between end centres. It is connected to the main piston and plunger rods by cross-heads and links. The crank shaft is directly over the main beam centre and a little below the base level of the cylinder, its journal being in the entablature. Connection from the beam to the crank is from a projecting horn, cast on the upper side of the beam, and at such an angle as to secure proper vibration.

The diameter of the steam cylinders is 25½ inches for the H. P. and 52 inches for the L. P., with a stroke of pistons of 9 feet. The horizontal distance from centre to centre of cylinders is 15 feet 2 inches, which is the same as from centre to centre of pumps. The exhaust steam from the H. P. cylinder is passed through chambers termed reheaters, which contain a large number of small brass tubes, through which steam of the boiler pressure circulates, the exhaust steam being outside of the tubes. By this means any moisture in the exhaust is re-evaporated, and it goes into the L. P. cylinder in a practically dry state.

As the connection of the steam pistons is to opposite ends of the beam they have alternate movements, and the weights are all practically carried on the main beam journals, which reduces the friction to a minimum. The distribution of steam is by means of gridiron slide valves, operated by grooved cams placed on a horizontal revolving shaft, which receives its motion by means of gearing from the crank shaft. The cams impart to the valves a short and rapid movement; the inlet valves of the H. P. cylinders are also used as cut-off valves, and are automatically controlled by the governor. The governor is so constructed that it will enable the engine to run at any required speed—between five and eighteen revolutions per minute—by the simple addition of weights to a scale beam.

In order to distribute the weight properly on the foundations the bed-plate is made very strong and massive. It consists of four cast-iron tubular girders, with their inner ends bolted to the beam pedestal, and

suppported on a heavy transverse girder, or bed-plate, resting on the central foundation piers. The outer ends rest on heavy masonry piers. The extreme length of the bed-plate is 39 feet 9 inches. The extreme width at the centre, abreast the beam pedestals 12 feet, and at the ends 16 feet. The engine is thus carried with the exception of the outboard pedestal, within a parallelogram 16×40 feet. The depth of the bed-plate girders is 3 feet. and their width across the bottom flanges is 3 feet. They are secured to the foundations by 12 bolts, 3½ inches in diameter. The total weight of the bed-plate, including the beam pedestals, which form a part of the same, is 53 tons.

Perhaps the most prominent feature of the engine is the pumps, which are of the single-acting plunger construction, 48 inches in diameter and 9 feet stroke. There are seven principal parts to each pump, viz.: The upper chamber, plunger stuffing box, delivery valve seating, centre-piece, lower chamber, inlet-pipe and plunger. These are shown clearly on the drawings 1, 2, 3, and 4, B. The upper chamber, as will be seen, is cylindrical in form, and may be likened to a large inverted kettle with a hole in the bottom. It is 9 feet 6 inches internal diameter, and 6 feet 11 inches extreme height. The metal is 1½ inches thick in the body and two inches thick in the flanges. The opening for the plunger stuffing box is 4 feet 9¼ inches diameter There is a delivery nozzle 48 inches in diameter, cast on the chamber, also pads for securing the same to the bed-plates. The plunger stuffing boxes are 4 feet 3 inches inside diameter and 3 feet 5½ inches deep, leaving a packing space of 1½ inches. The delivery valve seatings are of the form shown on sheet No 3 B. They consist of a heavy base 18 inches high, composed of two flanges, united by the frustrum of a pyramid 7 feet 3 inches diameter at the base and 6 feet 7¼ inches diameter at the top. Upon this base is cast the frustrum of a 9 sided pyramid 3 feet 10 inches high, having a diameter at base of 6 feet 11½ inches, and at the top of 4 feet 9 inches. To this pyramid are bolted nine rectangular valve seats, each 3 feet 6 inches long by 21 inches wide, and arranged for 3 valves 15 × 9½ inches which cover clear openings in the seats 13½ inches × 4½ inches. The valves are of rubber ¾ inches thick and have wrought iron back and face plates. They form their own hinges and their construction can be clearly seen on sheet No. 2 B and the example before us. The lower valve chambers are of cylindrical form externally about 7 feet 6 inches in diameter and 7 feet 10 inches high. Within these chambers are formed the foot valve seatings. which consist of inverted frustrums of a pyramid having 6 sides, the inscribed diameter being 6 feet 11½ inches at the top, and 41⅝ inches ditto at the bottom. There are 6 valve seats, each 6 feet 4 inches in length by 21 inches in width, and carrying 6 valves of the same dimensions as previously described for delivery. There are thus in each pump 36 suction and 27 delivery valves. The pump under the H. P. cylinder discharges through the pump under the L. P. cylinder. There is a force main from the latter 48 inches in diameter, upon which is placed at a distance of 28 feet from centre of the engine an air vessel 6 feet 6 inches in diameter and 10 feet 2 inches high. The grates or screens for the pumps consist of cast-iron frames, and wrought-iron bars two inches by ½

inch; these bars are two inches apart. The angle of all the valve seats is 45 degrees, and it is expected that no silt or débris of any kind will remain on them. It will be observed from the construction of the pumps that the movement of the water is opposite to that of the plungers, and that the deflection of the current is the easiest practicable under the conditions of inclined valve seats. The engines are provided with iron galleries at the base of the cylinders, which form the working platform. Also with iron floors at the level of the bed-plates, and at the top of the pumps, there has been built a tight wooden floor to prevent the escape of odors from the well. This floor has suitable traps for access to the bottom of the pumps.

In order to facilitate the removal of the pumps, without disturbing other parts of the engine, there is attached to each delivery valve seating four trucks, which can be dropped upon the foundation girders, which are provided with grooves for the truck flanges, and the same can be run back to a convenient position for hoisting.

The fly-wheels are 36 inches in diameter and weigh 36 tons each. The shaft is of wrought iron, 17 inches in diameter at journal and 20 inches diameter in the wheel. The total weight of each engine is very nearly 900,000 lbs., of which some 227,500 lbs. is in the pump and appendages. The capacity of the high-duty engines is nominally 25,000,000 gallons per 24 hours, against a maximum head of 43 feet. To accomplish this a speed of about 10¾ revolutions per minute must be maintained. The engines have been run at a rate which will insure a delivery of 42,000,000 gallons per 24 hours, and the performance was such as to leave no doubt that such a delivery could be permanently maintained —4 per cent. slip has been allowed in these estimates of capacity. The working pressure of steam will be 100 pounds per square inch, and with this pressure the number of expansions in the steam cylinders will vary from sixteen to twenty, in accordance with the varying head pumped against.

On account of the difficulty of obtaining a supply of water for the pumps no duty trial has thus far been practicable, but in the short runs that have been made a high duty has been foreshadowed.

The Low-Duty Storm Engines.

These are of the Worthington duplex type, and have steam cylinders 21 inches diameter. H. P.; 36 inches diameter, L. P., by 4-feet-stroke; they operate plungers which are double-acting, 45 inches in diameter; these plungers are carried in cases which are attached to two cylindrical valve chambers, having their axes parallel to the plungers, and which are very ingeniously arranged. both for access and efficient action. The valves are of the same construction as those in the high-duty engines. There is a new feature in the steam valve gear which merits notice; instead of the usual rock shaft motion the valves are operated by hydraulic power, through plungers which are driven by the air-pump levers, and communicate their motion to alternate sides of pistons attached to the valve stems. The action is as follows, as described by Mr. F. W. Jenkins, the inventor, who entitles his invention "The Hydraulic Link."

"Attached to the steam-chest of each engine there is a plain cylinder

CITY OF BOSTON, IMPROVED SEWERAGE.

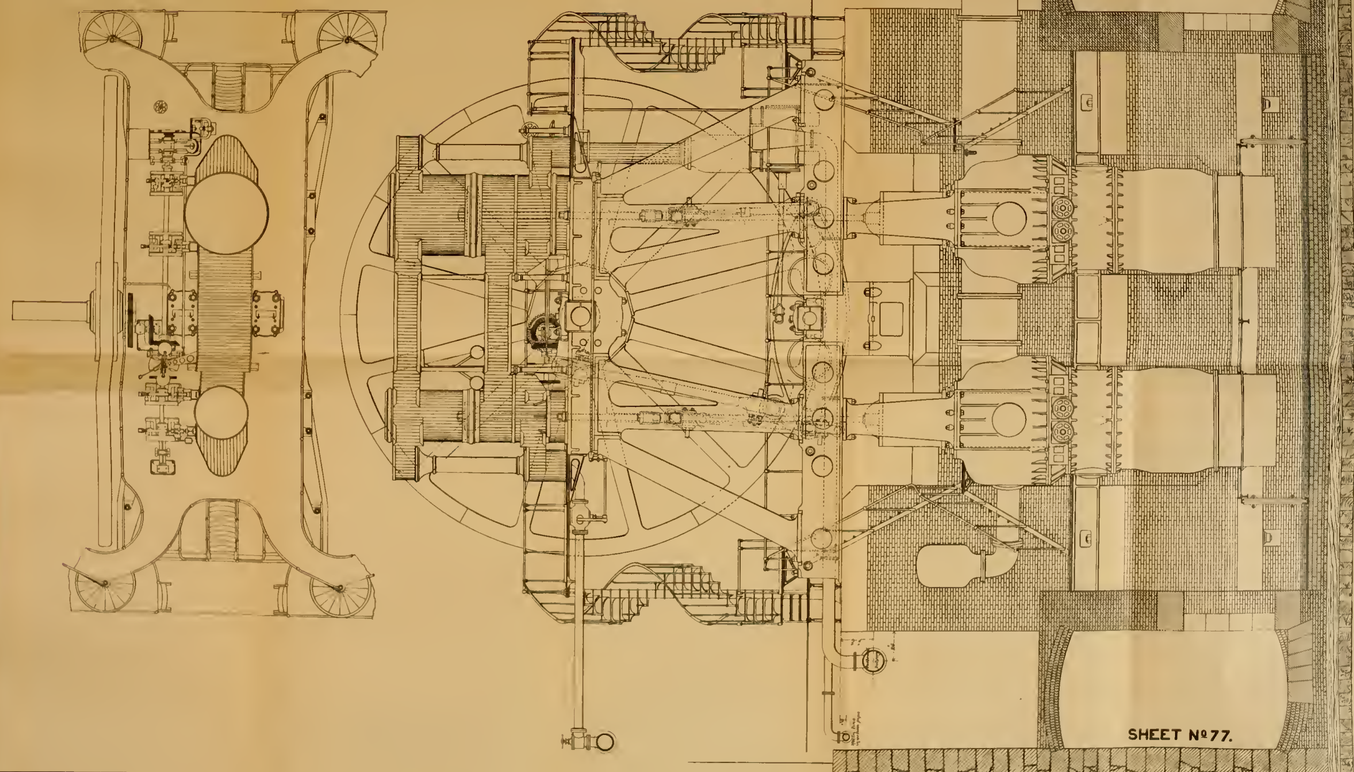
PUMPING ENGINES.

SIDE ELEVATION & PLAN.

Approved
J. P. Davis
City Engr

SCALE 3/16" = 1 FOOT.

E. D. Leavitt Jr. 1877



SHEET No 77.

The Heliotype Printing Co. Tremont St. Boston

in line with the valve rod, with a leather-packed piston, whose rod connects to the valve rod. The extreme stroke of this piston, when touching the head of cylinder, is sufficient to give the steam slide valve a full opening. From each end of this valve-driving cylinder a one-inch pipe is carried to two single-acting plungers working in proper and close-fitting barrels.

"These plungers are driven by a beam, or pair of short cranks on the end of the air pump rock shaft. We have thus two single-acting plungers, which, moving simultaneously, simply oscillate a column of fluid from one to the other, the pipe connection taking in the valve-driving cylinder on its road from one plunger cylinder to the other. With the cylinders and pipes completely filled with water or other fluid it is plain that one plunger provides space for as many cubic inches in its retreat as the other demands by its advance, and *vice versa*. So that we have simply a fluid mechanical link, or transmitter of motion confined in a small pipe. Theoretically, with the valve-driving cylinders cf the same capacity of the stroke of the actuating plungers, the movement of the valve, and its piston must be exactly corresponding to the displacement of the plungers, but leakage, or disarrangement of the correct position of the piston in valve-driving cylinders would in time cause them to lose position, so that the valve-driving piston might get to the extreme end of its stroke, and against cylinder head, while the plunger had still a small distance to travel. This would, of course, bring the whole power of the engine to bear in the valve driving cylinder and pipes and burst them. To avoid this a small supply tank is set at a level of a foot or two above the valve-driving cylinders, and the pipes have a branch connected to this tank, through a small valve chamber, containing two ordinary poppet valves, one a relief valve loaded with an adjustable spring, the other a supply valve. The spring on the relief valve is screwed down so that the pressure on the fluid is only 8 or 10 pounds above that required to move the valve-driving piston. Therefore, when the piston has reached the head of cylinder the relief valve opens at this moderately-increased pressure, and the surplus fluid is discharged into the tank. On the next stroke, should there be any deficiency, as there must be when the plunger travels further than the valve-driving piston, the supply valve admits just the proper quantity. In this way a small percentage more than is theoretically needed of the fluid is taken in and discharged at each stroke, and the apparatus is guarded against all danger of breaking down, or losing the length of stroke of the slide valve, even though the main piston rods should shorten their stroke by changes in pressure of steam or other working conditions.

"Again, an element of safety is introduced when, by any accident to the water valves, or breaking of the main plunger rod, the engine suddenly deprived of its load should run away. In such a case it is found that a very rapid stroke causes the relief valve to open, before the valve-driving piston can operate the slide valve. So that one dangerous stroke of the engine is the last, and the other side fails to move. In its application to the Worthington duplex pumping engine (to which this description applies) the steam slide valve of one side of the engine is driven by, and

corresponds to, the movement of the piston rod of the other side. To complete the four strokes (equivalent to a revolution, if connected to a crank shaft) one slide valve must move in the same direction as the piston moving on the opposite side, the other in the contrary direction. To do this mechanically through levers and rock shafts is cumbersome, vibratory and expensive on large water-works engines. With the hydraulic link it is accomplished by simply crossing the pipes on one side and running them parallel on the other. Six months' use at the B. S. pumping station seems to prove that this method of communicating the motion from the main piston rod to the slide valve is both inexpensive and reliable. A small pressure-gauge connected to the valve-driving cylinders indicates exactly the amount of power required to drive the slide valves—a dynamometer that cannot be impeached.

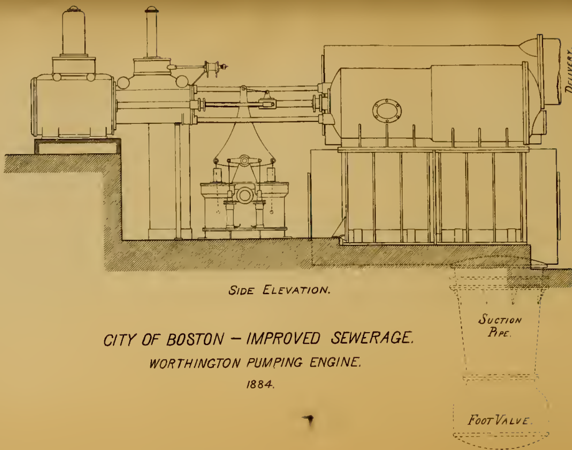
"The necessity of balancing the slide valves is by this arrangement easily determined, and their general condition of proper friction ascertained to a pound.

"It has been found by careful experiment that the valve-driving cylinders may be near or remote from the plungers, ten feet or a hundred making no difference in the certainty of action, except a slight increase of pressure due to friction through the connecting pipes, which can be obviated by increase in their size. The motion of the valve rods is smooth and steady, and of exactly the same character as the parent motion of the main piston rod of the engine."

The general construction of the storm engines will be readily understood from the drawings so that no further description is deemed necessary.

The Boilers.

There are two boilers for each pair of engines making four in all, and of precisely similar construction. They are of the horizontal fire-box tubular form, 31 feet $9\frac{3}{4}$ inches long over all, and 6 feet 8 inches diameter of shell; each boiler has two fire-boxes, 3 feet 6 inches wide, 5 feet 2 inches high, and 11 feet long, including the connection to the combustion-chamber. The latter is 4 feet long, and receives the products of combustion from both furnaces. Connected with it are 132 tubes, 3 inches external diameter, and 15 feet long between the tube sheets. The grates are 3 feet 6 inches wide, by 6 feet 6 inches long. The boilers are constructed of homogeneous steel throughout, varying in thickness from $\frac{5}{16}$ inch in the furnaces to $\frac{7}{16}$ inch in the shell, and $\frac{1}{2}$ inch in the tube sheets. They are double riveted throughout. The ends of the boilers above the tubes are connected by 8 stay rods $1\frac{7}{8}$ inches diameter in the body, and $2\frac{1}{4}$ inches diameter in the thread, with nuts outside and in. The crown sheets are sustained by stay bolts running to arches, which are riveted to the shell. The sides of the furnaces are braced by screw stays $\frac{7}{8}$ inch in diameter placed $4\frac{1}{2}$ inches from centre to centre. The boilers are supported at the fire-box end in cast-iron ash pits, and under the barrel by cradles and stools of cast iron, the latter resting on balls 2 inches in diameter, which allow for expansion in either direction. There are three cradles for each boiler. Each pair of boilers have a steam drum 24 inches in diameter and 19 feet 2 inches long. Steam is taken from the drums through a 10-inch pipe. The products of com-



Side Elevation.

CITY OF BOSTON — IMPROVED SEWERAGE.

WORTHINGTON PUMPING ENGINE.

1884.

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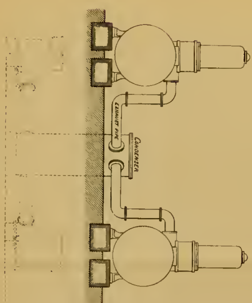
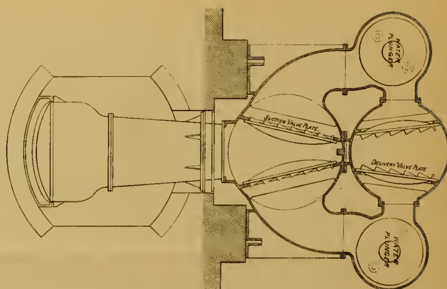


End Elevation.



Transverse Section through Pumps and Plungers.

CITY OF BOSTON — IMPROVED SEWERAGE.

WORTHINGTON PUMPING ENGINE.

1884.

The Heliotype Printing Co. Boston

bustion from each pair of boilers pass around the tubes of a flue-heater, which are eighty in number—2½ inches inside diameter and 14 feet 10 inches long. The ends of the tubes are connected by return bends; the tubes and bends are made of brass. They are placed upon a wrought-iron carriage having suitable truck wheels, and they can easily be removed from the flue for examination and cleaning. The construction of this heater can be readily seen from the drawing No. 6 *H*. The boilers are provided with the usual valves, cocks and gauges, which it is unnecessary to describe. The main steam pipe running from boiler-house to engine-room is 14 inches in diameter, of lap-welded wrought iron. The connection to each engine is by seamless wrought-iron pipe 7 inches in diameter. For supplying injection water there are two Worthington duplex pumps, having steam cylinders 7 inches in diameter, and plungers 14 inches ditto, with a stroke of 18 inches. These pumps deliver salt water into wooden cisterns from whence it is taken to the condensers of the engines.

Foundations and Wells.

The foundations consist of brick piers, capped with granite, between which the pump pits are located. The piers are 37 feet high above the timber floor, on which they rest, and are about 8 feet square, the central and end piers being connected by walls 3 feet thick. Below the foundation girders, the thickness of the piers is increased to 9 feet 6 inches. The distance from centre to centre of engines is 18 feet, and the length from out to out of foundation piers is 47 feet. The arrangement of the foundations is such that there is convenient space for getting entirely around the pumps. Inverts are turned between the walls or piers, so as to distribute the weight of each engine upon a space of 47 feet by 18 feet. There are two supply wells running the entire length of the engine-house. These wells are 9 feet wide, and about 17 feet 6 inches high to the crown of the arch which covers them. All the pocket-holes for foundations are covered by granite, and there are cast-iron washers about 12 inches square for each bolt.

The timber platform upon which the foundations of the building as well as the engines rest is 2 feet thick, and its bottom is 23 feet below grade zero.

LEVEES:

THEIR RELATION TO RIVER PHYSICS.

By Robert E. M'Math, Member of the Engineers' Club of St. Louis and of Am. Soc. C. E.

[Read February 27, 1884.]

Levees, or embankments against flood waters, have been resorted to since men first discovered the fertility of bottom lands, and doubtless will be for all time to come. They have their legitimate use and place, but there are limits to that use beyond which levees become dangerous and agents of evil. This danger line is approached whenever the levee system along a silt-carrying river attains a development which renders

their physical relation important. To these physical relations and dangers I invite the attention of the club.

Of late years it has been claimed for levees that, when perfected as a system along the Mississippi. they would cause an enlargement of the bed proper by concentrating volume, and hence increasing velocity and scouring power. As a result of these intensified forces, it is asserted that the bed will be generally deepened, its hydraulic capacity increased ; that eventually a general reduction of surface slope will follow, and a consequent lowering of the river in its bed. This lowered river would be the joy of the navigator, and the bottom lands, delivered from fear of overflow, would quickly become the terrestrial paradise.

Since levee systems have attained no mean development along the Lower Mississippi, and also along several Old World rivers, in some cases having a history covering six centuries, the results claimed ought to be evidenced by facts rather than assumption. So far from having such facts to support the claim, it has been a much debated question whether leveed rivers do not raise their beds. As to the Mississippi, the committee on outlets and levees of the Mississippi River commission was, after much search, able to say of average flood height : "There is no evidence that this has been raised since the settlement of the country, or by the building of levees." They also quote G. W. R. Bailey as saying : "There is no evidence that the normal flood line of the Mississippi River from Red River to the head of the passes (except where effected by cut-offs) is a fraction of an inch higher now than in 1717, before the commencement of the levee system ; but there is evidence that it is not higher." They could not find evidence of the slightest lowering.

Notwithstanding the universal negation by experience of the claim that levees will cause a lowering of the flood plane, the assertion has been reiterated with pertinacity, and it is said that recent observations corroborate the utility of levees as a means of channel improvement. To this claim I enter a general denial, and say that, on the contrary, every fact of experience and observation when correctly interpreted goes to prove that the result of the flood action in a silt-carrying stream is always obliteration of the navigable channel through the shoals, as it existed before the high stage, and also impairment of the capacity as a channel of discharge. The latter result being in part the consequence of the former.

As correctly stated by Lieut. S. S. Leach, Secretary of the Commission, in summing his discussion of the Carrollton series of observations [appendix E to Rept. of Com. for 1882, page 111] : "The first effect of the approaching flood is to impede its own discharge and the impediment outlasts the flood." His diagrams, plate 2, Figs. 1 and 2, show the fact very plainly, because consecutive observations are connected by lines and order of sequence is shown by numerals. Similar observations at other stations are given in detail in appendix F to the same report. The diagrams, plates 1 to 6, do not properly show the facts, because consecutive observations are not connected or indicated, but a mean line is drawn which is a fair mean, still it must be said that means are an illegitimate mode of studying a problem whose elements are not thoroughly known. In this case the mean

will allow a conclusion tolerating, not justifying, the concentration view; while the observations themselves, taken in order of sequence, show that discharge underwent relative loss as the river approached flood, and a fresh loss with each minor oscillation of stage.

It is not possible to enter upon a discussion of observations, nor to cite many facts in this paper; but I hope to show the logical and physical fallacy of the purely speculative reasoning which led to the levee, or concentration of flood water view.

As a preliminary, I call attention to three modes of dealing with the volume of a river in an engineering sense—dispersion, concentration and equalization. In the popular mind these are respectively associated with outlets, levees and reservoirs, as means of applying the several principles.

Happily, dispersion by outlets has been eliminated from discussion as unworthy of further consideration, though very plausible when first suggested.

As between concentration and equalization there is in terms the following common principle, but, as will appear, a widely different interpretation of it:

"If the normal volume of water in a silt-bearing stream flowing in an alluvial bed of its own formation be permanently increased, there will result an increase of velocity, and consequently of erosion and silt-bearing power, an increase in area of average cross-section, the ultimate lowering of the surface slope; and conversely, if the normal flow be decreased in volume there will ensue a decrease of velocity, silt-transporting power and mean sectional area, and an ultimate raising of the surface slope."

The interpretation favoring concentration requires that normal, in the above statement, should be taken as synonymous with average, and that the condition of "permanent" increase should be satisfied by the increase of an occasional volume.

The equalization interpretation insists that the principle stated is true only when normal volume means the volume which can be permanently increased; that is, the minimum or low stage volume.

Increase of normal volume, in the concentration sense, requires that more water should pass through the channel in a given time. In the equalization sense a more uniform distribution of the quantity is demanded, whether the total be the same, greater or less.

Expressing the ideas graphically, stage being plotted as ordinates and discharge as abscissas, concentration would be satisfied with a volume represented by a triangle resting upon its apex, and would add volume so as to prolong the upper side. This would certainly increase the area and average value, or the side of the equivalent rectangle having the same altitude.

Equalization demands that the figure itself shall approach the equivalent rectangle.

Dealing with realities and possibilities the representation must be a trapezoid, with its longer side uppermost. Concentration would seek to increase the inequality of the sides. Equalization would forbid anything which tends to increase inequality, and would foster every influence which can be made to diminish it.

Should a concentrationist find a drunken man, to be consistent he must furnish him more whisky, and press him to drink it. The equalizationist would sit down and tell him how much better it would be to time his drinks. If neither of them cured the poor fellow the latter at least would be clear of the accusation of having killed him if he died.

Concentration of flood waters not only increases the long side of our trapezoid, but does so to some extent at the expense of the short side, for overflow water is stored in swamps and absorbed by the soil and the subsequent slow discharge from the swamps and saturated soil forms part of the low stage volume.

I leave the geometrical illustration with the remark that the value of a force is measured by the capability of application at suitable time and place to useful work, and proceed to show that no useful work can be done by floods, because the work they do is at the wrong time and place.

It is well established that bars are formed during and by floods, and that the higher and more lasting the flood the higher and more extended the shoals. It is also well established that low stages cut out and remove bars, and that the smaller the low stage volume the less effective will be the cutting out. Hence it must of necessity be that increase of flood and decrease of low stage volume is evil, and only evil in result. This is concentration. Conversely, increase of low stage volume, and particularly if it can be made by detention of part of the flood, is good, and only good in result. This is equalization. The contrast exhibits the relation of the two principles to navigation.

As affecting discharge we know that bars act as submerged dams. Their crests define the origin of discharge, and velocity, curves for the reaches above. Raise the bars and the curves are lifted, so that for equal height on the gauge discharge will be less, and for a given volume the height on gauge will be greater. The looping of the Carrollton discharge curve already mentioned (shown in accompanying diagram) is due to shifting origin of curves, and similar looping would appear at all the observation stations if the data given in the printed tables of the commission report, 1882, were platted and the order of sequence preserved. This brings the discussion again to the fact of the approaching flood bringing an impediment to its own discharge, which outlasts the flood, and closer to the cause.

The river, immediately after a low stage, is always at its highest efficiency as a channel of discharge. As a result of the cutting-out process it is then really lowered in its bed. If the efficiency following a prolonged low stage could be maintained during flood time the river would rarely overtop its banks. [See broken line of Fig. 1.] On the other hand, after a flood the river is always in a low condition of efficiency, as shown by discharge observations, because at such times it is actually raised in its bed, the bars being then high. A succession of floods without a prolonged low stage interval will be cumulative in their deteriorating effect and will go higher and higher, perhaps with less actual volume. Observed differences of volume for equal stage on the gauge amount to hundreds of thousands of cubic feet per second, and yet there are men and engineers who look for good results from heaping the floods still higher by confining them laterally.

I must pause here and define what is meant by low and high stage volume in this discussion, lest any suppose that virtue is claimed for smallness of volume and evil charged to mere largeness. Natural streams are alternately wider and narrower, shoaler and deeper. The sectional area is consequently variable and, since the wider parts are also the shoaler, and the narrower parts the deeper, a change in the relative areas of these places occurs as the river passes from one extreme of stage to the other. Taking any two related sections, one from a wide and one from a narrow part, there is an intermediate stage when their areas will be equal. At that stage velocity as a mean will be the same at both sections. If the river rises the wider section becomes the greater in sectional area, the narrower section will then be likely to enlarge by scour and the wider to diminish by deposit. On the other hand, if the river passes below the intermediate stage of equal areas the wide section will cut out and the narrow fill. As examples of this change I cite from the Craighead sections:

	Low water, 1879.		*High water, 1880.	
	Width, ft.	Area. Sq. ft.	Width, ft.	Area. Sq. ft.
Section 1	6,010	39,620	8,840	260,000
Section 20	2,317	56,660	5,600	199,850

*26.6 feet higher.

Since mean velocities at the sections were inversely as the areas, the extent of change is manifest.

Low stage volume as used in this discussion means all volumes below the stage of equal areas. It therefore includes a considerable range on the gauge, but less of the rising than of the falling stage. In other words, all volumes during the cutting out periods are low stage volumes and all during the time when bars fill are high stage volumes. The former work good, the latter evil, but both work.

A misconception of this distinction between useful and injurious work has led to much false reasoning and to the advocacy of injudicious plans for the improvement of the river.

It is claimed for levees that they will conserve and utilize the forces of the river now wasted by overflow and outlet discharge. The argument being that the loss of this force causes shoals to obstruct navigation and renders the bed insufficient to convey the full flood discharge. The issue is so vital, and the argument in favor of levees so well calculated to mislead, that it is necessary to enlarge the discussion and look at the subject in every light.

Conservation of energy in scientific language has a definite meaning, and expresses an important truth. In popular addresses and special pleadings it is often a mere catch phrase to tickle the ears and appeal to the conceit of half-informed and wholly deceived audiences.

Expenditure of energy in work is quite another thing than utilizing it. The potential energy of the Mississippi at any point in its course is the mass of water multiplied into the mean height of the mass above sea level. Descent to sea level, no matter when or how, involves the expenditure of that energy in useful, injurious or neutral work. The available energy at any point is that part of the potential energy which can be applied then and there. The question is, can capacity for useful work be increased by rendering all the potential energy at once available by con-

centration? which means keeping the flood waters together in a compact body and discharging them in less time than if allowed to overflow. That is, the concentration is in space and time. Does such concentration of natural forces usually result in useful work? The kindly breezes which are so grateful on a hot day converging to a centre and concentrating in space and time become the tornado. Is its work useful? Concentrated light will blind the eyes; concentrated heat will burn; concentrated electricity is the lightning; concentrated steam will burst the boiler; concentrated rains produce a deluge. From these examples it will be seen that the presumption is against concentration as a means of securing useful work. Distributed energy, not diffused, is useful; concentrated energy is destructive.

To take a more practical view of the matter: All admit that, if the volume of the Mississippi was invariable, there would be no call for its improvement. The channel would be deep enough, the bends would be adjusted to the slope and current, and the banks would be stable. In contrast with such an ideal condition, we may put a river which varies from a large flood volume to an insignificant rill, like the Platte: such a stream will be widespread, without definite banks or channel. The Mississippi, below the Red River, approximates the first state, there being but one grand oscillation in each year from low stage to high and return. The range of volume is about 1 : 10. Below the Ohio we have an approach to the contrasted state; there are several great oscillations in a year, and the range of volume is about 1 : 22. The lesser variation of volume below Red River is consistent with practical stability of bed and banks. The channel is continuously deep, because the banks do not cave and the river does not develop wide places. Under the greater and more frequent volume variation below the Ohio, bed and banks are unstable, wide places develop, and consequently shoals. A perfected system of levees, extending from Commerce, Mo., to the forts below New Orleans, will, if they stand, carry the volume variation at the Ohio a long way toward the Gulf, just as we have recently seen the narrow valley of the Ohio convey an overwhelming flood, with little diminution of destructive energy, from Cincinnati to Cairo. Flood waves from each main tributary will pass to the Gulf as distinct oscillations, and the combination of two or more waves will then, as now, form the flood volumes which mark epochs in the river's history.

The flood of 1882 was relieved of about six feet of its height in the first 100 miles below the Ohio by overflow into the St. Francis basin. The remainder deeply submerged the banks and overtopped levees of considerable height. It is computed that the full volume of that flood, if effectually confined by levees, would have reached ten feet higher from Gayoso to Memphis, supposing the channel efficiency to remain what it actually was during that flood. Observation and experience would require us to expect further impairment of channel efficiency, had the flood reached greater height. Levees to hold such a flood must be at least 13 feet above flood line of 1882, or say 20 feet in average height, plus an undeterminable allowance to meet impaired channel efficiency. The risk of loss behind such levees would be vastly greater than that from natural unrestrained overflow.

Variation of volume in effect makes the high and low stage river two distinct and discordant streams. Increase the variation and the discord will be greater. It is now the cause of changing banks and bars. Carrying the excessive variation near the Ohio toward the Gulf, by confinement between levees, will carry cause and results also. If a man has an unbalanced fly-wheel, which shakes the building and endangers property and life, he does not remedy it by adding more weight to the overweighted side and running the wheel faster. But the engineer who advocates concentration of flood waters in order to get more mass and greater velocity would commit both of these fatal errors.

Work in abundance is done by floods now, but the work, being applied to the wrong places, is always injurious.

It is said, let us concentrate the flood water between levees ; the augmented volume and height will then cause increase of velocity and scouring power. All these statements are true. The question is not of the amount, but of the utility of force. The practical error lies in the assumption that increased scour will remove bars, enlarge the bed and afford additional capacity for discharge. So far from this being true, flood scour in every instance that has come under observation has been attended by diminished capacity for discharge ; and, conversely, every case of diminished capacity (which was not obviously due to back water), has been attended by flood scour. The two things are concurrent. For instance : During the flood of 1882 the cross section at Red River landing enlarged by scour within the bed 40,000 square feet ; the discharge for equal stages, at the same time and place, diminished 140.000 cubic feet per second. The scour, if general, furnished material at the rate of nearly 7,800,000 cubic yards per mile of river.

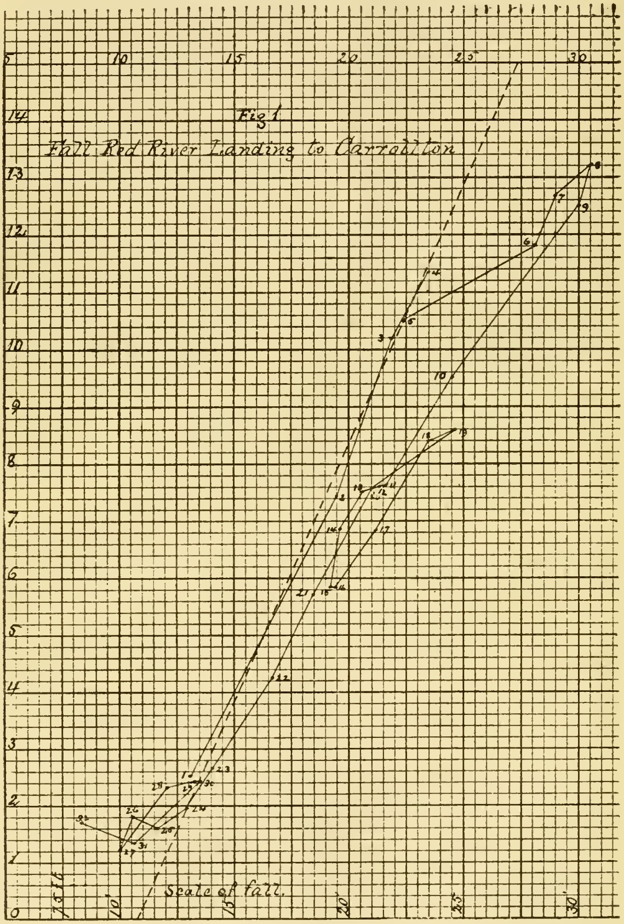
At Clayton, on the Upper Mississippi, below the junction of the Wisconsin, a remarkable decrease of discharge attended the spring and autumn floods of 1881 ; in both cases the section enlarged, in the latter to the amount of 3·6 in depth and 5,400 square feet in area, or at the rate of 1,056,000 cubic yards per mile of river so affected.

Facts sustaining the statement above occurred at every point of observation, proving that the conclusion reached from the Carrollton observations of 1880, already cited : "The first effect of the approaching flood is to impede its own discharge, and the impediment outlasts the flood "—is a general truth, and for a very good reason. The flood provokes local scour, and material scoured at one part of the river's course must be deposited at some other. I have already shown where scour and deposit will take place. So long as the geometrical relations upon which scour and deposit depend continue it is impossible that any useful or desirable result can follow the action of floods, be they great or small, restrained or free, concentrated or diffused. They are an evil, and the greater the worse.

Experience and sound theory are in entire accord concerning this matter. If the river was to remain continually at flood stage the formation of a channel proportioned to the flood volume would be desirable and would most certainly be attained. For it is the effort of the river at any given time to form a bed adapted to the discharge of its then volume. When bed and banks are unstable this effort results in enormous changes

within the bed as volume varies. If the bed and banks were as unstable as water the adaptation of channel to volume could be made, but since they are not, and a wide difference between low and high stage volume is unavoidable, the direction of engineering effort ought obviously to be to render the passage from one extreme to the other as infrequent and gradual as possible.

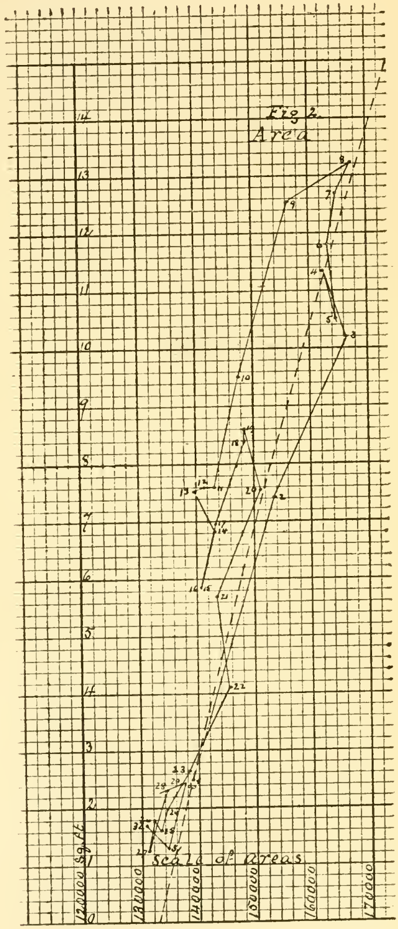
All lines of reasoning, from fact or theory, point away from con-



centration of flood volume and converge upon the central principle equalization of volume. The only objection that can be urged against this principle is that it does not promise all that men may wish, but it does promise all that men can do. If it cannot do all imaginable good it has the solid merit of refraining from evil.

The natural operation of this principle through the detention of a vast

volume of flood waters in swamp reservoirs of the St. Francis, Yazoo and Tensas basin renders Louisiana below the Red River inhabitable. The progress toward a violation of the principle made during the season of active levee construction in 1882 caused the river at New Orleans in 1883 to reach a higher stage than in 1882, though the volume in the later year was much less. This experience bids fair to be repeated in 1884. A little more progress in leveeing above Red River, and the lower coast will be inundated every high water.



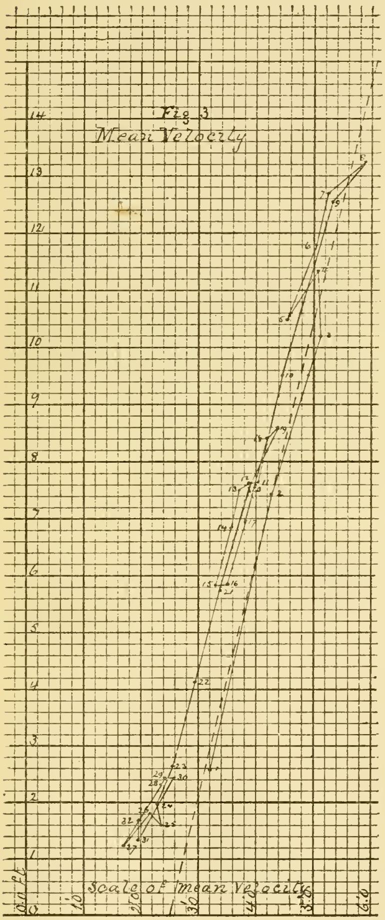
The waters which in 1882 went into the basins named were returned to the river during March, April, May and June in volumes that overshadowed the variations in the supply at Red River landing, so that the discharge curve at that observation station presented a smooth convex outline, though similar curves at Columbus, Ky., and Helena, Ark., showed two well defined waves. The returning water, therefore, did for the lower river what we have seen to be desirable—it reduced the number of oscillations and rendered the change from flood to low stage more gradual. Equalization is, therefore, not a mere speculation, but a beneficent principle in most active and important operation.

On the other hand, after July 1, 1882, the discharge at Red River Landing rose and fell in harmony with the upper stations and tributaries, showing that, in the absence of flow into or from the swamp reservoirs the oscillations noticed at the Ohio may and do extend nearly to the Gulf. They would do so to a greater degree if concentrated in space and time by levees throughout the distance

As to the idea that concentrated flood waters will enlarge the bed, we may learn from the Ohio. Floods there are frequent enough and concentrated enough to develop their merits as channel formers, if such they have. Has any one discovered any progress toward increased capacity to discharge floods, or any benefit to navigation?

The relation of levees to river physics has now been shown to be a

dangerous one when silt movement is a prominent feature in the river, as it is in the Mississippi. It must not be understood that the results shown would all be developed short of the extension of levees into a general system. It is the proposed adoption of levees as a system for the whole river, from Commerce, Mo., to the forts below New Orleans, which renders a discussion of the subject timely and important. Applied to isolated plantations, or even to districts of moderate extent, the physical results of levees will not be apparent. A man may drain his house waste and fecal matter into the nearest ravine or ditch, and no ill may result; but if he has a thousand neighbors, and they all do the same, disease and death will surely follow. In like manner, levees are among the make-shift devices which may be tolerated for a time, as the best that can then be done, but which must give place to better things.



The subject, it will have been observed, turns very largely upon two general conclusions:

1. That floods fill bars and low stages remove them.

2. The advancing flood brings an impediment to its own discharge which outlasts the flood.

Both of these depend upon silt-movement, and that is very largely the result of scour of bed and bank during flood time.

The first of these conclusions is more fully discussed in Appendix K to Report of Mississippi River Commission for 1881, pp. 242, 257. Of this discussion the Commission say in their report (page 16): "Papers of this description are not without material value, since they eliminate from further discussion some well-determined points, and thus narrow the field of conjecture."

The conclusion has been repeatedly used in testimony before Congressional committees as being the true manner of bar formation and removal. Failure under cross-questioning to explain the obvious contradiction between this fact and the benefit to low-water channel which it

was claimed would result from levees, compelled the Congressional committee of last winter to report adversely to the plans of the Commission.

The second general conclusion has not heretofore been applied in a public discussion. It is brought forward in Appendix E to the report of the Commission for 1882. To the two papers named I refer any who may wish to follow the subject.

As proof of my statement, that low stages do actually lower the river in its bed, and that high stages raise it, I add diagrams of the Carrollton discharge observations, in which Fig. 1 shows the fall which existed in the river from Red River Landing to Carrolton at the dates of the several observations ; Fig. 2 the areas of the discharged section ; Fig. 3 the mean velocities at that section ; and Fig. 4 the discharge.

It will be observed that the greatest efficiency of discharge occurred when fall was least.

Taking, for example, observations at nearly equal stages :

Date.	No. of Obs.	Area.	Stage.	Discharge.	Mean Velocity.	Fall in 194 Miles.	Fall per mile.
		Sq. ft.		Cub. ft.	Ft. per sec.	Ft.	
Dec. 17. 1879...	1	138,900	2′.52	444,396	3′.20	16.2	0.0835
Sept. 20, 1880...	30	137.700	2′.46	357,748	2′.60	16′.5	0.0850
Difference.....		+ 1,200	+ 0′.06	+ 86;648	+ 0.60	− 0.3	−0.0015
Jan. 3. 1880...	2	153.495	7.46	654,941	4′.27	19′.50	0.1005
July 31, 1880....	20	151,290	7.57	558,020	3′.89	21′.00	0.1082
Difference.....		+ 2,205	− 0.11	+ 96,921	+ 0′.38	− 1′.50	−0.0077
Jan. 16, 1880....	3	166,400	10.20	854,000	5′.11	21′.85	0.1126
May............	9-10	149,850	10.20	698,000	4.66	25′.30	0.1304
Difference.....		+ 16,550	0.0	+156,000	+ 0.45	− 3′.45	−0.0178

Observations at intermediate points enable me to subdivide the 194 miles as follows:

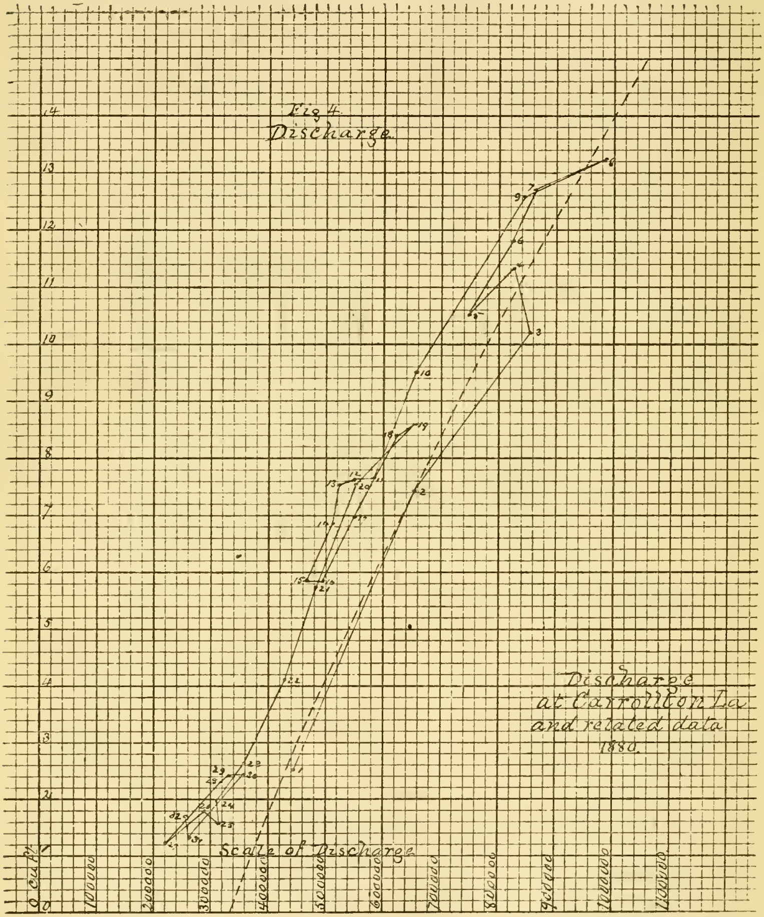
		Dec. 17, 1879. Fall per mile.	Aug. 20, 1880. Fall per mile.
Red River Landing to Baton Rouge	70 miles.	0.0870	0.1097
Baton Rouge to College Point.......	73 "	0.0633	0.0452
College Point to Carrollton....................	51 "	0.0457	0.0363

whence it very plainly appears that the increase of fall at the later date was limited to the first 70 miles below Red River Landing. The lower divisions both flattened.

In the accompanying diagram the broken line of Fig. 1 shows the probable variation of fall from Red River Landing to Carrollton, if the conditions prevailing from December 17, 1879, to January 26, 1880, had continued. That of Fig. 2 shows the sectional area, which would have been found if the section of December 17, 1879, had remained unchanged. Those of Figs. 3 and 4 show what mean velocity and discharge would have been if the conditions between December 17 and January 26 had continued.

The height of flood is not therefore measured by the volume of water,

but depends largely upon the condition of the river bed. The approaching flood brings an impairment of that condition by building up the shoals, and that impairment outlasts the flood. Hence successive flood waves will, for equal quantities of water, go higher and higher. To this result there is no assignable limit. Therefore levees can never be made



safe as protection against overflow in a river carrying large quantities of silt. The physical action of levees has also been seen to provoke silt movement, and therefore to increase the very evil they profess to guard against.

ELECTRIC MOTORS.

By Augustine W. Wright, Member Committee on Railroads, Streets, etc., Western Society of Engineers.

[Read March 18, 1884.]

You have all read the very interesting paper on "The Dynamo-Electric Machines," by Prof. Arey, of the Civil Engineers' Club of Cleveland. This is intended to supplement that of Prof. Arey by briefly describing some of the electric motors that have been constructed. The following accounts are taken from the files of the *Scientific American, Railroad Gazette, American Engineer, Electrician and Electrical Engineer, London Engineering, Van Nostrand's Electrical Magazine, Popular Science Monthly*, Appleton's Dictionary of Mechanics, and Allison's Dictionary of Electricity.

What *is* the marvelous force that we call electricity? Electricity has been defined by Grove as "that affection of matter or mode of force which most distinctly and beautifully relates other modes of force, and exhibits, to a great extent in a quantitative form, its own relation with them and their reciprocal relations with it and with each other." Wells wrote "Electricity is a subtile agency or force, without weight or form, that appears to be diffused through all nature, existing in all substances without affecting their volume or their temperature, or giving any indication of its presence when in a latent or ordinary state. When, however, it is liberated from this repose it is capable of producing the most sudden and destructive effects, or of exerting powerful influences by a quiet and long-continued action."

Tyndal wrote: "We have every reason to conclude that heat and electricity are both modes of motion; we know experimentally that from electricity we can get heat, and from heat, as in the case of our thermo-electric pile, we can get electricity. But although we have, or think we have, tolerably clear ideas of the character of the motion of heat, our ideas are very unclear as to the precise nature of the change which this motion must undergo in order to appear as electricity—in fact, we know, as yet, nothing about it."

One of the oldest electric-motors was that of the Abbê Salvatore del Negro, Professor of Natural Philosophy at Padua. A dynamo machine made by him and recently exhibited bears the date of 1830. It consisted of a magnet movable around an axis situated at about one-third of its length, the upper extremity of which was capable of oscillating between the two branches of an electro-magnet. A current being sent into the electro-magnet, passed through an 8-cupped mercurial commutator, that the oscillating magnet controlled by means of a rod and a fork. As a result of such an arrangement, when the magnet had been attracted toward one of the poles of the electro, this very motion of attraction. acting upon the commutator, changed the character of the current, and the magnet was repelled toward the other branch of the electro and so on. This apparatus possessed an interesting detail. The movable magnet where it touched the poles of the electro abutted not against the iron itself, but against the insulating wire that covered it! Either by

accident or design the author thus avoided those inconveniences connected with remanent magnetism which afterward embarrassed other inventors.

March 1, 1834, an English patent was taken out by Henry Pinkus for a "dynamic traveler," intended to propel vessels and carriages on canals, railways and common roads by means of magnets and electricity as well as by pneumatic power.

In 1838 Mr. Cook, of Saratoga, N. Y., made an interesting exhibition of an electro-magnetic machine in Barclay street, New York. The whole apparatus was of the most simple construction, consisting of two sets of magnets, one revolving within the other. The external magnets being excited by the fluid generated by the action of an ordinary galvanic battery, while the polarity of each magnet was constantly and regularly changing, a perfectly uniform motion was communicated to the cylinder which might be increased indefinitely as additional force was applied. This machine was thirty inches in diameter and contained seventy-eight magnets, each weighing four pounds. The machine in full operation made eighty revolutions per minute, considerably more than could be obtained by the force of one man.

Prof. Jacobi, of St. Petersburg, by means of an engine on this principle, in 1838 and 1839, propelled a boat on the Neva at the rate of four miles per hour. This boat was 28 feet long by 7 feet wide, and drew nearly 3 feet of water. It contained ten persons. The engine was worked by a Voltaic battery of 64 pairs of platinum plates, excited with nitric and sulphuric acids, and propelled the vessel through the medium of paddle wheels.

In 1840 experiments were made by Prof. Page with three chemical electrical batteries upon the Baltimore & Ohio Railroad, but they did not prove a success.

In 1842 an electric-magnetic engine, constructed by a Mr. Davidson, was tried on the Edinburgh & Glasgow Railroad, an account of which, with the drawings, was published in the "Practical Mechanics and Engineers' Magazine," in November of that year. The carriage was 16 feet in length, 6 in width, and weighed about 5 tons. Speed about 4 miles per hour.

In 1869, M. Griel, a French military officer, invented an electric-motive engine, based on the action of currents on currents. He stated that he could apply his machine to railroads, and by causing the electricity to wash from the wheels of the machine upon the rails, ascend any grade with the greatest facility.

In 1872 the Gentry Electric Railroad Car was exhibited at Nashville, Tenn. This engine was composed of a number of magnets. The armature was made to work by breaking and closing the circuit. It was proposed to build an elevated railroad upon poles set in the curbstone and carry mails and light packages at a speed of one hundred miles per hour!

In 1879 Dr. Werner Siemens introduced his electric railway at the Berlin Industrial Exhibition. During the summer of 1880 it worked at the Brussels Exhibition, and May 16, 1881, the first electric railway was opened for passenger traffic at Berlin by Messrs. Siemens and Halske.

It was about 2,500 metres long, and connected the station of the Anhalt Railway with the Military Academy ; gauge, 1 meter. The permanent way was same construction as upon ordinary railways—modern cross-ties and steel rails, the latter being connected, in addition to the usual fish-plates, by short straps of iron, bent in the shape of a bridge, to allow contraction and expansion of the rails, and also to reduce the electrical resistance. Currents were low tension, and it was not necessary to provide further insulation, and no difficulty was experienced in using the one rail as positive and the other as negative conductor. About one-third of a mile from the Lichterfeld the primary machine with its steam engine is erected in the engine house of the water-works, and the current is conveyed from there to the rails by ordinary underground cables. The car similar to an ordinary tram-car holding 20 people can be made to run backward and forward, each end being provided with a starting lever, brake handle and signal bell. The dynamo-machine placed underneath the car transmits its movements to the wheels by means of spiral steel springs. The wheel tires are insulated from the axles and are in electrical connection with brass rings fastened on the axles, but insulated from them. Contact brushes press against these brass rings, and from them the current is conducted to the dynamo-machine and sets it in motion. Greatest speed allowed is 12.4 English miles per hour. In 1882 a second car was put on this railroad, when it was found that the two cars moved in either direction as safely and with the same speed as a single car, the only difference being that when two cars were on the rails the steam engine that provided the electric current had to exert twice the power. On the tramway from Charlottenties to the Spandauer Berg, in the western outskirts of Berlin, Dr. Siemens overcomes a rising grade of one in thirty. The line constructed as an ordinary tramway is distinguished by two thin wire cables about 9 inches apart and carried on telegraph poles about 15 feet high. These cables are parallel to the track, and upon them runs a small carrriage on 8 wheels. A wire extending from this to the tramway car dynamo conveys the electricity to the latter. This was the form adopted at the Paris Electrical Exhibition, but General McClurg informed me they experienced not a little difficulty from this carriage getting off the wire tracks along which it must travel with the same speed as the car. This plan was also adopted by Messrs. Siemens for the electric railroad at the collieries of the Donnersmarckhütte Co. in Silesia. The speed on the latter road is 8 miles per hour.

In 1881 a new form of dynamo machine was devised by C. F. Heinrich. The main improvement was in the form of the armature, which the inventor has been led to adopt by a careful study of the Gramme ring and the way in which currents are induced in it. He found that the inner side of the ring, that furthest from the field magnet, produced in the coil a current opposed to the one induced on the part of the coil immediately in front of the poles of this magnet, and to this extent weakens the current and causes heat in the coil. When the field magnet is powerful and the ring thin this effect is reduced, but the induction action of the further side of the ring is not wholly eliminated. He therefore makes the ring channeled or of horseshoe cross section, the coils of wire being

wound on the outside only. This removes the metal from the inner portion, and at the same time allows such a free circulation of air around the wires of the coil where they cross the base of the horseshoe that heating is prevented.

Mr. T. A. Edison built a narrow-gauge road about two miles in length at Menlo Park. The track was not smooth, but he ran trains of passenger car and electric locomotive, surmounting heavy grades. The rail was connected at regular distances with one of the terminals of a dynamo in a central station, the other rail being similarly connected with the opposite terminal. The motor contains a dynamo, but has the appearance of an ordinary engine with cab, but without smoke stack. A speed of forty miles per hour is said to have been obtained. Mr. Stephen D. Field spent some years in perfecting his system of electric-motors for railways. The electric railroad at our Exposition of Railway Appliances was a combination of the Field and Edison ideas. The frame upon which this motor was mounted was 5 × 12 feet, carrying a dynamo of the Weston type, with suitable attachments. To the revolving part of the motor was attached a pinion, working a bevel gear wheel upon a shaft at the forward end of the engine. Pulleys and belts transmitted the motion to the driving wheels. A friction clutch upon the latter enables the driver to disconnect the motor. The electricity was communicated from the stationary dynamo to this motor by an extra rail laid between the ordinary track rails. The electricity was taken from this rail by brushes bearing upon each side, thus doing away with the necessity of cutting the axle in two to insulate it. The lever upon the dynamo was invented by Mr. Field, and enabled the engineer to regulate its speed with the greatest ease.

The invention of W. M. Thomas, of Cincinnati, is well worthy of investigation. Here the electric current from the stationary dynamo is conveyed along the tracks by two copper wires placed in an iron tube between the tracks. This tube is open top and bottom; the former to allow contact with the wires from the motor, and the latter to allow water and dirt to drop through and keep the wires clean. The motor has five wheels, the two forward ones simply an ordinary truck. The rear pair, being larger, serve as driving wheels, and through them the power is applied. The fifth wheel, back of them, is wedge-shaped, and divided by an insulator of gutta percha, each side touching the copper wire carrying the electric current. Above this wheel is the electric cut-off, moved by a lever, for reversing the current and consequent motion of the car. The details of taking up the current from one conducting wire, the passing it to the motor and from that to the other conductor, the power being in the meantime transmitted to the drivers by ordinary mechanism, are ingenious.

In 1882 the Austrian ministry granted a concession to the Southern Railway Co. to run from Mödling to Bruhl, in the suburbs of Vienna, about two miles, single track, gauge 1 meter, grade not to extend 15 in 100, maximum speed 12½ miles per hour.

In October, 1881, work was begun on an electric railway between Portrush and Brush Mills, in Ireland, by Sir W. Siemens. The capital stock was £45,000, or about $225,000. The line, 6 miles in length, is worked

by electricity generated by turbine wheels, gauge 3 feet. One half mile is in a street in Portrush, the balance of the way is in a country road. The rails are laid on one side of the road, and ordinary traffic cut off by raised curb stones. It has grades of 1 in 35, and occupies a space 6 feet wide of the street. An underground cable carries the electricity to a T iron supported on posts 10 feet apart. It is 22 inches from the inside of the track rail, and 17 inches above the ground, and to some extent forms a fence. From this T iron the electricity reaches the motor through two brushes, one at each end of the motor pressed against the T iron by steel springs. At each road crossing this T iron has to be left out, and the current is carried across this opening by buried insulated copper wires. The car is long enough to reach across most of these openings so that one brush touches. In dry weather this rail has to be lubricated, but in wet weather the dampness suffices. From the brushes the current passes to a commutator worked by a lever, thence through the axle boxes to the axles, through the wheel tires to the rails. The latter are insulated and carry the return current back to the generating machine. The speed is 10 miles per hour, but 12 miles have been attained. At first there was trouble from leakage of electricity, but this was largely overcome.

In 1883 the Electric Railway at Wimbledon was in operation. The motor attained a speed of six miles per hour with 19 passengers, over a very rough track. The current was generated from a Weston dynamo, driven by a 12 horse-power engine, and carried by two flat copper bands an inch broad, laid in the bottom of a groove in long wooden troughs between the rails, supported on wooden blocks saturated with pitch. The insulation was quite perfect. The motor consisted of four external magnets coupled together in similar poles, and an armature of 16 magnets traveling between the external magnets and cutting all the lines of force. It is mounted on an ordinary carriage, and the current is drawn from the one copper band, passed through the motor and returned to the other copper band by means of two trailing chains dropping upon the copper.

The Daft Electro-Motor, invented by Leo Daft, was given a trial November 24, 1883, on the Saratoga, Mt. McGregor & Lake George R. R., near Saratoga, N. Y. The small motor hauled a passenger car well filled on a mile and a half of road successfully, but on the return trip jumped the track at a sharp curve and was wrecked. The gauge of this road is 3 feet, and 1½ mile was fitted for electric operation by tightening the rail joints of the existing track and laying a middle rail or conductor upon wooden blocks saturated with pitch as at Wimbledon. A sharp curve and 93 feet grade has to be surmounted. This motor weighed 4500 pounds. It was 9 feet 6 inches long, 5 feet wide, and 3 feet above the rails. The armature and field magnets were inclosed in a box on the platform. In front was the driver's seat and a dash board with three switches and a key-board. The right switch makes and breaks the current. The left switch controls an electric brake and the centre switch and key-board control the combination of the coils. The reverse lever is on the right. Two phosphor-bronze wheels press firmly upon the centre rail by steel springs, carrying the electric current to the switches and key-board, thence to the electric engine

and through the driving wheels to the outer rail. A counter shaft communicates motion to the driving wheels. Double flanged pulleys are used.

The generators of Mr Daft's manufacture weigh 1200 pounds. There are two, occupying a floor space 4 feet by 5 feet, driven by a 25 H. P. engine. The current is conveyed from them to the rail underground. The motor took 17 tons of car and passengers, and no difficulty was experienced during snow or rain.

I will now call your attention to the invention of M. Camille Faure, of France, patented October 20, 1880, and February 9, 1881, called an accumulator, and an improvement on Planté's secondary battery. It was constructed as follows: Two sheets of lead were taken, 7.87 inches wide, one sheet being 23.62 inches long and 0.04 inch thick, the other 15.75 inches long and 0.02 inch thick. Each plate was covered on both faces with a layer of red lead reduced to a paste with water, 1.76 pounds being spread over the larger plate and 1.54 pounds over the smaller. On each face thus prepared a sheet of parchment paper was placed and the whole introduced into a sheet of thin leather. One plate was then put on top of the other and rolled up. Strips of rubber were interposed placed obliquely. The roll was then placed in a cylindrical lead vessel, the outside of which was strengthened with copper bands and the inside covered with red lead and leather to increase the useful surface of the battery. One projecting stem from the lead plate was then bent over and soldered to the inclosing cylinder, which is ready for use when it has been filled with water containing 10 per cent. sulphuric acid. This apparatus weighs 20 pounds. One of these lead plates becomes oxidized by the passage of an electric current through the cell, and is recommitted into the metallic state when the charging current ceases, yielding a current while undergoing this latter transformation. Once charged this battery may be kept a considerable length of time without losing its power, and gives out a current steadily in a manner similar to an ordinary voltaic cell. The Planté cell was not of commercial value, as its capacity was small and it required a considerable time to charge it. These difficulties M. Faure seems to have largely overcome by coating the plates with minium (red lead), whereby their chemical dissimilarity, and, consequently electrical capacity, is greatly increased. When the charging takes place the minium on one plate is further oxidized to the peroxide and that upon the other reduced to the metallic state, a current being given one while these plates are assuming their original condition. The cell is said to give 80 per cent. of the current used to charge it. A secondary battery means a galvanic battery, which, as at first put together, has no tendency to give a current, as above described, but if a current of electricity be passed through it of sufficient tension to decompose the fluids which it contains, will give a current in the opposite direction, due to the recombination of the separate parts of the decomposed fluids. The older forms consisted of two plates of platinum, preferably coated with spongy platinum immersed in a weak mixture of sulphuric acid and water, the action in this case being that the charging current decomposed the water (either directly or as the result of chemical action set up by decomposing the

acid fluid) into oxygen and hydrogen which gases were absorbed by the platinum plates, the oxygen by one, the hydrogen by the other. When the charging battery is removed the secondary battery will give a powerful current until all the oxygen and hydrogen absorbed by the plates are recombined in the form of water. According to Sir W. Thomson a Faure cell of the spiral form weighing 165 pounds can store 2,000,000 foot-pounds of energy or one horse-power one hour. The improved accumulator of Faure-Sellon-Volckmar, weighs about 75 pounds and gives 1 H. P. one hour.

The invention of J. S. Sellon is described in the English patent as relating to "the use in the construction of secondary batteries of perforated plates or sheets, roughened, serrated or indented, composed of lead, carbon or platinum, upon, in or against which plates spongy or finely-divided lead or other salts or compounds of lead or other suitable substances or compounds are or may be held or retained." The new accumulators of E. Volckmar and J. S. Sellon at the Crystal Palace Electrical Exhibition were stated to contain each five horse-power of energy acting for one hour, or one horse-power acting five hours, etc. The cell consisted of a series of twelve metal plates, 15 inches $\times$ 20 inches $\times$ $\frac{5}{16}$ inch thick, of some alloy, and perforated with $\frac{1}{2}$-inch round holes, as close as they could be punched or cast. These plates were alternately connected in series like the plates of a condenser, and joined to two stout terminals, which were the poles of the cell. The holes were filled with a metallic paste, the composition of which was not divulged, but may be guessed from the fact that metallic lead was reduced on the negative plates, and peroxide of lead on the positive plates. The spaces between the plates (about one inch) were filled with acidulated water containing 10 per cent. sulphuric acid. This was all contained in a wooden box 30 inches square and 7 or 8 inches deep. Each cell weighed 375 pounds, of which the metallic composition weighed 295 pounds. Allow me to quote Edward M. Bentley, who said: "The popular conception of a secondary battery as a store-box, in which electricity is bottled up like soda-water and drawn off at will, is very erroneous. There is, to be sure, a condenser which actually stores up electricity; but a secondary battery ready for use contains no electricity whatever. It is simply an apparatus whose elements are in such a chemical condition that upon being placed in external electrical connection a current will be generated therein."

It has been proposed to operate street railways by means of electricity obtained from accumulators. The Electric Power Storage Co. built a street passenger car in 1883, carrying 46 passengers. It weighed, complete, without passengers, $4\frac{1}{2}$ tons. The accumulators were placed under the inside seats. Fifty Faure-Sellon-Volckmar cells were used, each 11 inches $\times$ 13 inches $\times$ 7 inches, and weighing 80 pounds. These accumulators were capable of working the car seven hours. A Siemens' dynamo placed under the car was connected with the accumulators by an insulated wire. A driving belt transmitted the motion from the dynamo to the axles of the wheels. In starting the car, the electricity was taken from the accumulator to the dynamo by means of a movable switch. The power required could be increased or diminished by using a larger or smaller number of cells. At night this car was lighted by four Swan lamps.

In conclusion, the applications of electricity, so far as I know of them, as a motive power for street railways in crowded cities, are not a practical success. Here in Chicago, for instance, the public would not submit to more poles in the streets. There is a loud and deep outcry against the poles now obstructing our thoroughfares. From a railroad point of view there is the expense of plant, etc., etc., and the great cost of operation. A French syndicate tested the system of M. Deprez transmitting electricity in Paris. In these experiments it appeared that 6.21 H. P. was put into one dynamo-machine, revolving at the rate of 590 revolutions per minute, and connected by wires to another machine making 365 revolutions per minute, the length of wire corresponded to 5.28 miles. The latter machine gave out 2.03 H. P. upon the brake. This amounts to a useful duty of 32.7 per cent., the rest being lost. It is but fair to state that a much larger percentage of useful effect is claimed for electricity.

Mr. Bentley says: "On a large scale electricity as a motor is only useful in transferring power to convenient localities, as when a machine which generates a current is driven by a distant waterfall, but the transmission of power into electricity and then its retranslation from electricity into power entail serious losses. That the electric motor must remain subordinate to steam, water, or original force until a new and cheaper source is discovered.

"Two thousand applications for patents in electricity were filed at U. S. Patent Office during 1882, of which number about two-thirds were granted."

The British Association Standards for measurement of electricity, taking the names therefor from those who have been most prominent in this service are as follows:

Ohm, for resistance. It equals the resistance of an iron wire 4 millimeters in diameter about 100 meters long. Volt, the unit of electromotive force, is nearly equal to one Daniells cell, but has no real standard. Ampère, for intensity. It is the standard measure of intensity formerly known as a weber, but quantity was also included in the latter term. The latter quality is now coulomb for quantity. This is the quantity of electricity which is forced through the resistance of 1 ohm by a current with the intensity of 1 ampère in one second.

I make no claims for originality in the foregoing paper, but have given not a little time and labor to the collection of the facts into one paper, and trust it may not prove uninteresting.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ST. LOUIS ENGINEERS' CLUB.

MARCH 26, 1884:—The St. Louis Civil Engineers' Club held a meeting in the directors' room of the Mercantile Library, with President Woodward in the chair, and twenty members and eight visitors present.

Mr. C. H. Sharman, Chief Engineer of the Illinois & St. Louis Railroad, was elected a member, after which the following persons were proposed for membership: Prof. E. A. Engler, recommended by W. B. Potter and C. M. Woodward; N. W. Perkins, recommended by C. M. Woodward and W. H. Bryan; K. Tully, recommended by Robert McMath and J. B. Johnson; J. A. Vail, recommended by C. F. White and V. C. Bassitt; J. A. Ockerson, recommended by Robert Mc Math and J. B. Johnson.

The Secretary read a letter from Mr. C. E. Illsley, in which the price of the JOURNAL for two years was inclosed, requesting that he be allowed to resign his membership.

It was decided that the action of the Club at the previous meeting, regarding Mr. Illsley, should be reconsidered and his resignation accepted.

A list of engineering periodicals and publications received by the Club was announced by the Secretary, and he was instructed to have them placed on the reading-room tables of the library.

Mr. D. C. Humphreys then read a paper on "Engineering Photography." He illustrated his remarks by the instruments used in engineering photography, and by photographs that had been taken.

At the conclusion of the reading of the papers Prof. Potter spoke of the importance of the subject in all engineering projects, and said he hoped Mr. Humphreys would give the Club the benefit of his further experience.

Mr. T. D. Miller, city gas expert, then read a paper on "Photometric Tests," with especial reference to the relative value of different kinds of gas burners.

The subject was discussed by Messrs. Woodward, Potter and others. After the President had announced the programme for the next meeting the Club adjourned.

J. B. JOHNSON, Sec'y.

OFFICERS AND MEMBERS OF THE ENGINEERS' CLUB OF ST. LOUIS.

MARCH 26, 1883.

C. M. Woodward, *President.* Robert Moore, *Vice-President.*
J. B. Johnson, *Secretary and Manager for the Journal.*
E. D. Meier, *Treasurer.*

W. H. Alderdice, Assistant Engineer U. S. N., Prof. Steam Engineering, Washington University, St. Louis, Mo.

Theodore Allen, Steamboat Builder, South St. Louis, St. Louis, Mo.

C. T. Aubin, Engineer Board of Underwriters, 508 Chamber of Commerce, St. Louis, Mo.

W. Bartlett, Contractor, De Soto, Mo.

Norman C. Bassett, Mechanical Engineer, Agent for Cram Bros.' Mfg. Co., 620 Chestnut street, St. Louis, Mo.

G. C. W. Belcher, Manufacturer, 2646 Washington avenue, St. Louis, Mo.

A. H. Blaisdell, Steamboat Builder, South St. Louis, St. Louis, Mo.

William Bouton, Assistant City Surveyor, 2909 Park avenue, St. Louis, Mo.

M. P. Brazill, Surveyor in Street Department, City Hall, St. Louis, Mo.

Charles I. Brown, Assistant Engineer St. Louis & San Francisco Railway, Springfield, Mo.

William H. Bryan, Mechanical Engineer, with Pond Engineering Co., 709 Market street, St. Louis, Mo.

P. Buehner, Mechanical Engineer, 237 East Seventh street. St. Paul, Minn.

George Burnett, Jr., Principal Assistant Engineer St. Louis Belt Railway, City Hall St. Louis, Mo.

Henry Burnett. Assistant Engineer Sewer Department, City Hall, St. Louis, Mo.

A. J. Chaphe, Chief Engineer City Water-Works, 917 Penrose street, St. Louis, Mo.

F. A. Churchill, Iron Broker, corner Third and Locust streets, St. Louis, Mo.

H. Constable, General Agent Worthington Pumps, 414 North Third street, St. Louis, Mo.

J. W. Cordes, Engineer and Superintendent Camp Spring Mill, St. Louis, Mo.

E. C. Darley, Mining Engineer and Contractor, Seventh and Pine streets, St. Louis, Mo.

James B. Eads, Civil Engineer, Third and Chestnut streets, St. Louis, Mo.

Henry Flad, President Board of Public Works, City Hall, St. Louis, Mo.

Geo. W. Fisher, Superintendent Fulton Iron Works, Second and Carr sts., St. Louis, Mo.

Thos. W. Fitch, President Harrison Wire Co., St. Louis, Mo.

Edward Flad, Assistant in Water Department, 1119 Valle avenue, St. Louis, Mo.

E. E. Furney. U. S. Assistant Engineer Missouri River Improvement, 1415 Washington avenue, St. Louis, Mo.

Thomas Featherson, District Engineer in Street Department, City Hall, St. Louis, Mo.

Carl Gayler, Bridge Engineer Street Department, City Hall, St. Louis, Mo.

W. Paul Gerhard, Chief Engineer Durham House Drainage Co., 127 East Eighty-sixth street, New York.

Edwin Harrison, Manufacturer, Chouteau, Harrison & Valle, St. Louis, Mo.

O. A. Haines, Carondelet, South St. Louis, Mo.

Jas. W. Hill, Mechanical Engineer, with Fairbanks Scale Co., 304 Washington avenue, St. Louis, Mo.

Joseph Hill, Superintendent St. L., Vandalia & T. H. R. R., 100 North Fourth street, St. Louis, Mo.

M. L. Holman, Chief Assistant in Water Department, City Hall. St. Louis, Mo.

H. S. Hopkins, Bridge Builder and Contractor, 112 North Fourth street, St. Louis, Mo.

D. C. Humphreys, U. S. Assistant Engineer on Missouri River Improvement, 1415 Washington avenue, St. Louis, Mo.

J. B. Johnson, Professor of Civil Engineering. Washington University, St. Louis, Mo.

Jacob Johann, General Master Mechanic Wabash, St. Louis & Pacific R. R., Springfield, Ill.

Richard Klemm, City Surveyor, 1734 Missouri avenue, St. Louis. Mo.

E. F. Leonard, Secretary St. Louis, Alton & Terre Haute R. R., Springfield, Ill.

C. V. Mersereau, U. S. Assistant Engineer on Mississippi River Improvement, 2638 Geyer avenue, St. Louis, Mo.

E. D. Meier, Member of firm of Adolphus Meier & Co., 102 North Main street, St. Louis, Mo.

Robert Moore, Civil and Sanitary Engineer, 325 Chestnut street, St. Louis, Mo.

T. D. Miller, City Gas Inspector, 622 Locust street, St. Louis, Mo.

Philip N. Moore, Geologist and Mining Engineer, Superintendent Slate Creek Iron Co., Olympia, Bath County, Ky.

J. W. Meier, Member of firm of Adolphus Meier & Co., 102 North Maine street, St. Louis, Mo.

C. W. Melcher, Mechanical Engineer, 322 Pine street, St. Louis, Mo.

James E. Mills, Geologist and Mining Engineer, Quincy, Plumas County, Cal.

James H. Morley, Civil Engineer, St. Louis, Iron Mountain & Southern Railway, St. Louis, Mo.

John H. Maxon, President Lindell Railway Co., 2928 Washington avenue, St. Louis, Mo.

H. C. Moore, Civil Engineer, 1118 St. Ange avenue, St. Louis, Mo.

T. A. Meysenburg, President St. Louis Bolt and Iron Co., 509 North Third street, St. Louis, Mo.

Thomas H. Macklind, District Engineer Street Department, City Hall, St. Louis, Mo.

R. E. McMath, Sewer Commissioner, 3709 Page avenue, St. Louis. Mo.

Edward Molitor, Chief Draughtsman for Mississippi River Commission, 2828 Washington avenue, St. Louis, Mo.

Julius Moulton, Civil Engineer in Harbor and Wharf Department, City Hall, St. Louis, Mo.

Frank H. Pond, Member of Firm of Pond Engineering Co., 709 Market street, St. Louis, Mo.

George H. Pegram, Chief Engineer Edge Moor Iron Company, Wilmington, Del.

William B. Potter, Professor of Mining and Metallurgy, Washington University, St. Louis, Mo.

S. Rockwell, Civil Engineer, St. Paul, Minn.

A. Rauschenbach, Assistant Street Commissioner, City Hall, St. Louis, Mo.

S. Bent Russell, Assistant in Water Department, City Hall, St. Louis, Mo.

E. Saxton, Civil Engineer and Contractor, Kansas City, Mo.

P. W. Schaumleffel, Chief Engineer St. Louis Lead and Oil Works, Second street and Cass avenue, St. Louis, Mo.

J. A. Sedden, United States Assistant-Engineer Missouri River Improvement, 1415 Washington avenue, St. Louis, Mo.

C. Shaler Smith, Chief Engineer St. Louis Bridge Co., 213 Washington avenue, St. Louis, Mo.

C. H. Sharman, Superintendent Indianapolis & St. Louis Railway, St. Louis, Mo.

Frederick Shickle, Manufacturer. Twelfth and Papin streets. St. Louis, Mo.

A. W. Smith, 800 North Main street, St. Louis, Mo.

J. Sobolewski, Inspector for St. Louis Gas Co., 515 Olive street. St. Louis, Mo.

J. B. Stone, Manufacturer of Wire Rope, 1818 Gratiot street, St. Louis, Mo.

H. G. Tidemann, Mechanical Engineer, with Adolphus Meier & Co., 102 North Main street, St Louis, Mo.

Eliot Todd, Manufacturer, 917 North Second street, St. Louis, Mo.

J. F. Wangler, Boiler Maker, 1019 North Main street, St. Louis, Mo.

William E. Worthen, Civil Engineer, 63 Bleecker street, New York.

B. Warren, Civil Engineer, Indiana, Bloomington & Western Railway, Indianapolis, Ind.

D. W. Wellman, U. S. Assistant-Engineer, in charge of the Survey of the Missouri River, 1415 Washington avenue, St. Louis, Mo.

H. A. Wheeler, Instructor in Mining Department, Washington University, St. Louis, Mo.

Chas. F. White, Superintendent Shop Work, Washington University, St. Louis, Mo.

Thos. J. Whitman, Water Commissioner, City Hall, St. Louis, Mo.

Wm. Wise, Assistant Sewer Commissioner, City Hall, St. Louis, Mo.

C. M. Woodward, Dean Polytechnic School, Washington University, St. Louis, Mo.

WESTERN SOCIETY OF ENGINEERS.

March 18, 1884 :—The 182d meeting of the Society was held, President Cregier in the Chair.

In the absence of the Secretary, Mr. Liljencrantz was appointed Secretary *pro tem.*

The minutes of the preceding meeting were read and approved.

The Committee appointed at the previous meeting to consider and report on changes in manner of holding regular meetings, were called on for report. The Committee asked for further time, which was granted.

Topical Committees were called upon for reports.

Mr. A. W. Wright, for the Committee on Transportation, etc., presented the following :

" In the absence of the Chairman I would beg to report that your Committee on Transportation, Railroads, Canals, Streets, etc., have not met, owing to the removal of the Chairman to Texas. The Chairman has had every minute of his time occupied so far by private business, but hopes in the near future to give attention to the interests of the Society, and to set a good example to our resident members. As a member of the Society, I would express my deep apprecia-

tion of its loss by the removal of the Chairman of this Committee to so great a distance. In the meantime I have prepared two papers and presented them to you for the Committee. Allow me to take advantage of this opportunity to urge the members to *discuss* the various papers presented from time to time. The discussion is often of much greater interest and value than the paper, serving as a ground-work. Your Committee would respectfully urge the members of the Western Society interested in Transportation, Railroads, Canals and Streets to send papers and notes of works they have in hand to the Committee.

"Respectfully submitted, AUGUSTINE W. WRIGHT,
"Member Com. on Railroads, etc."

Mr. Liljencrantz, for the Committee on Rivers and Harbors, reported that a paper on a new construction of crane for iron dredge was being prepared by Mr. R. A. Brown.

Mr. Bates, for the Committee on Heat and Fuel for Industrial Purposes, reported that a paper was in course of preparation by a member of that Committee.

Mr. B. Williams, for the Committee on Lighting, Heating, and Ventilating, reported progress.

The President suggested the desirability of securing a collection of photos, of suitable size, of the members of the Society.

Mr. McHarg made the following motion, which was unanimously adopted :

"Moved that the Secretary be instructed to invite members to send cabinet photographs of themselves to him for presentation to the Society."

Mr. A. W. Wright, of the Committee on Transportation, etc., read an interesting paper on "Electric Motors," which subsequently was discussed by the members.

The Chair directed that the receipt of a copy of the "Transactions of the American Institute of Mining Engineers" be acknowledged by the Secretary.

General Fitz Simons moved that it be the sense of the Society, in the absence of the Trustees, that the paper presented by Mr. Wright be printed.

Motion prevailed.

[*Adjourned.*] G. A. M. LILJENCRANTZ, Secretary pro tem.

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

ON THE SEWERAGE OF KANSAS CITY.

BEING A REVIEW OF A PAPER ON THE SAME SUBJECT BY MR. O. CHANUTE, C.E.

By Robert Moore, Member of the Engineers' Club of St. Louis.

[Read March 12, 1884.]

The paper "On the Sewerage of Kansas City," read by Mr. O. Chanute before the Kansas City Academy of Science in November last, and reprinted in *Engineering News* Feb. 16, 1884, merits some notice on the part of the large class of engineers to whom his conclusions appear unsound and his advice bad. For his widely known ability and well deserved reputation as an engineer are such, that whatever he says will have great weight with the public and with engineers who are not experts in the matters he discusses.

The purport of his advice is: that Kansas City should abandon the construction of sewers for storm water, except in special cases, and instead thereof adopt the separate system of sewerage as "finally perfected" by Col. George E. Waring, Jr., and constructed at Memphis.

The premises upon which this conclusion is based are substantially these:

1. Sewers for storm water are, with exceptions in special cases as already noted, unnecessary, street gutters and other open channels being all that is required.

2. The adoption of the separate system, to which, as he tells us, "the name of Mr. Waring has been justly attached," will involve a large saving of money, the amount for Kansas City being, as he figures it, a little more than one million dollars, or about fifty per cent. of the cost of sewers on the combined system.

3. But, most important of all, the system proposed will in a sanitary view be much the safer, the use of storm water sewers for purposes of house drainage being, as compared with the separate system, inimical to the public health.

Let us consider each of these propositions.

First, then, is it true that surface channels will be sufficient for the carriage of storm water in a town like Kansas City?

If the experience of other cities can be applied to this one, the answer to this question must be very strongly in the negative. In them the universal experience is that as soon as the city becomes at all crowded or closely built the surface channels for storm water become nuisances which it is necessary to abate by the construction of sewers. And as a rule the first sewers in all large cities were constructed for this purpose and no other. The causes of trouble in this case are several.

1. The cross gutters necessary to carry the water over intersecting streets are serious obstructions to public traffic.

To any one who has watched the effect of these gutters in the unsewered parts of a large city in obstructing the passage of vehicles, or who has ever had charge of sewers and listened to the appeals for street corner inlets to abate the cross gutters a simple mention of the matter is enough. And, in Kansas City, I am told, the City Engineer cannot keep up with this demand for new inlets.

2. The accumulation of water in the gutters during heavy rains and on steep grades, such as prevail in Kansas City, soon becomes destructive and dangerous.

A correspondent there writes me thus:

"Surface water is universally felt to be a nuisance. It runs in torrents down steep streets, scouring out gullies and carrying mud and macadam before it till it is checked at a break in the grade and spreads into a lake. There it deposits its load, fills up gutters, overflows cellars, and takes a fresh start."

3. Where the grades are flat there is trouble of a different kind. The water then collects in stagnant pools which in warm weather soon become offensive. Examples of this can be found in every city, but I know of none better than in New Orleans, where a large part of the sanitary work necessary in warm weather is the flushing of the gutters.

In the larger and natural channels precisely the same thing takes place. It is found impossible to keep out of them rubbish and refuse matter from factories and stables, and they become polluted. This may happen even if nothing goes into them but the washings from the streets. The analyses of Prof. Way, cited by Baldwin Latham [*Sanitary Engineering*, page 43], show that in London, which is kept cleaner than any American city, the drainage water from the streets in time of rainfall is quite as impure as any sewage.

This pollution of the streams, even in the thinly populated outskirts of cities, is of constant occurrence. Some notable examples of it exist in St. Louis, and, if I am rightly informed, others equally good can be found in Kansas City. The only remedy is to straighten and pave the channel, so that the water will flow off before it has time to become offensive, or, if the stream be not too large, convert it into a sewer.

4. But even if the streams were to remain pure and clean, the time comes, sooner or later, in every city, when the ground which they occupy is needed for other uses.

In London, for example, the old River Fleet first degenerated into the Fleet Ditch, and then became such a "grievous and dangerous nuisance"

that it was converted into the Fleet Sewer, over which there now passes the dense traffic of Fleet street. In like manner in St. Louis the old channel of Mill Creek is now the Mill Creek sewer, and is covered over with streets, railroad tracks and buildings. And so in every city, the old streams, unless they are so large as to make it impossible, are arched over and the ground which they occupied converted to purposes of business.

Surface channels may answer well enough, or at least be tolerated, in a small town or sparsely settled village, but for the full development of a city sewers for storm water are as necessary as the paving of its streets, and their construction should enter into the plans of every town that expects to become a city. But Kansas City has already a population estimated at more than 80,000, and is growing at a rate which, if continued, will bring it in 1890 up to 125,000, and in 1900 up to 245,000, with a strong probability that these figures will be exceeded. Clearly this is not a place for any plans but those which are appropriate to a city.

Moreover the steep grades which prevail in Kansas City, ranging as they do in the sewers from two up to twelve feet per hundred, have the effect of very greatly reducing the sizes of the sewers, as compared with what would be needed elsewhere. A sewer of 6.3 feet diameter with a two per cent. grade, or one of 4.4 feet diameter with a twelve per cent. grade, will carry as much water as a sewer ten feet in diameter having the grade of the Mill Creek sewer in St. Louis.

To all this the paper under consideration opposes very little, the surface removal of storm water, except in special cases, being almost taken for granted without argument. The author, however, remarks in one place that in Kansas City "storm water can be quickly and cheaply got rid of by open gutters combined with a few storm sewers" for the reason that "the grades are steep and the slopes short," and "in our climate," he adds, "the rains are needed to wash the streets."

Now, while it is true that the grades are steep, running as high as twelve feet per hundred, the map shows the shortest slope in the direction of the streets, from the crest of the ridge to the river, to be 3,500 feet. But on such grades storm water in the gutters becomes a serious matter after it has run five or six hundred feet. Beyond that distance it becomes a raging torrent, sweeping everything before it and rendering the cross streets for the time being impassible. I should say that a thousand feet, or less than one-third of the shortest slope, was the limit of endurance, leaving the other and lower two-thirds to be in any event provided for by sewers.

The argument that "the rains are needed to wash the streets" has, in this connection, little or no force, inasmuch as the combined system of sewerage still allows the rain to fall on the streets and run into the gutters, thus utilizing it as a cleansing agent as fully as the separate system, but without allowing it to become a source of inconvenience or destruction.

In another place Mr. Chanute says that on account of the great activity in building up and digging down in Kansas City, storm sewer will be obstructed by rubbish, unless they be made "large enough for men to go into them and clean them," as in the French practice.

But even if it were impracticable to exclude rubbish from the sewers by trapping the inlets, as is successfully done elsewhere the world over, the steep grades, to which he has just referred, will not only cause a reduction in the sizes of the sewers, as we have already seen, but will also produce a velocity of flow so great that, unless there be some criminal carelessness, the danger of stoppage may safely be neglected.

Assuming, therefore, as I think we must, that storm water sewers will be a necessity, it is certainly cheaper to use them for house drainage than to construct another system for that purpose. So that in place of the saving which Mr. Chanute figures as the result of the policy which he proposes, we may put down a loss ultimately of an amount about equal to the cost of the second system.

Now, of course, if there were any difficulties of sewage disposal in the case, if the sewage had to be pumped or treated by any of the methods of filtration or irrigation, this greater cost might be justified. But nothing of this kind exists or is alleged. Of both systems alike the Missouri River is to be the final and sufficient outlet.

But is there, last of all, any sanitary reason for abandoning the combined system and introducing in place of it the separate system, as is recommended in the paper under discussion? This, of course, is the most important question of all, far outweighing any considerations of cost.

Of Mr. Chanute's convictions on this point his paper leaves us in no doubt. Nearly two years ago, he tells us, when on a visit to Kansas City he learned of the proposed adoption there of the combined system of sewerage. Thinking this would prove to be a mistake, and feeling a great interest in the welfare of the city, he called together a few citizens and the reporters of the public press, and, citing the testimony of other men and the experience of other cities, pointed out "that not only would the combined system be very much more expensive than the separate system," but "would also largely increase what physicians call 'zymotic diseases,' such as typhoid, diphtheria, scarlet fever, etc., a class of diseases from which Kansas City had hitherto been happily remarkably free." Again he says, "The combined system is said by sanitarians to involve grave dangers to public health," whilst, "on the other hand the separate system is free from the slightest taint of suspicion. It is universally admitted to be healthy and safe."

Now, if true, these statements are certainly important. But when we consider that the system which they condemn is almost the only one used in large cities, that its introduction has always been attended with greater sanitary benefit than any other agency, and that it is indorsed as promoting the public health by the ablest and most experienced sanitarians and engineers in the world, such men as Bazalgette and Lindley and Chesebrough, we are bound before accepting these opposing conclusions of Mr. Chanute to demand of him nothing less than the most clear and positive proofs. What then has he to offer?

First of all he presents an argument from the nature of the case, to this effect. The house drainage does not fill the large sewers of the combined system more than one-twentieth full. Hence, to use his own words, "the result necessarily must be that during at least nine-tenths of the

time the Kansas City sewers will be nineteen-twentieths full of noxious gases, which physicians tell us are dangerous to life."

Now as the gases here spoken of are the results of the ordinary processes of fermentation and decomposition, there can be no difference in the amounts evolved from the same quantity of sewage in different sewers, unless there be a difference in the time of exposure, that is in the velocity of the current. But in any given case the two classes of sewers will be of the same length and the same grade, and there will be no difference affecting velocity excepting in the hydraulic radius or mean depth of flow. In the ordinary egg-shaped sewers, however, even this is almost the same, whatever difference there is being in the vast majority of cases offset by the greater volume of water admitted to the larger sewer. So that if we compare well-built sewers of the two classes we shall, as a matter of fact, find no material difference in the two cases either in the velocity of flow or in the quantity of the products of decomposition. But there will be the great difference that these products will in one case be mixed with a volume of air vastly greater than in the other. And as in other cases the dilution of a poison lessens the danger, it certainly seems not unreasonable to believe that, unless some special means be taken to counteract the effect of size, the larger sewer will be the safer. On this point we have some positive evidence which is worthy of consideration.

In 1875 there occurred in Croydon, about eight miles south of London, an epidemic of enteric, or typhoid fever, in which in a population of 81,000 there were nearly 1,200 cases. The Local Government Board, the central sanitary authority in England, sent Dr. George Buchanan, who has since been promoted to the high position of Chief Medical Officer to the Board, to examine into the causes of this outbreak.

It should here be premised that Croydon had been drained since 1851 by a system of small pipe sewers put in under the auspices of the General Board of Health, who were at that time the champions of this system. After one or two typhoid epidemics, of which the first occurred in the next year after the sewers were completed, a large number of the four and six-inch mains were taken up and nine-inch pipes substituted. Open grated manholes were put in in large number and three-inch iron ventilating put on to the houses, which were connected with the sewers without any intervening trap after the manner recommended and adopted in Memphis by Col. Waring. In fact nothing was wanted but the flush-tanks of Mr. Rogers Field, not then invented, to make the drainage system identical with that which Col. Waring has since patented. But there were flushing arrangements of a different kind, so that the resemblance to the Waring system was still very close.

The investigation of Dr. Buchanan was of the most thorough kind, and his conclusion, as given in his printed report to the Local Government Board, was that the sewers of Croydon had been the chief agency in propagating the fever. After mentioning other cases of the same kind "in Rugby, in Carlisle, in Chelmsford, in Penzance, in Worthing," all sewered with small pipes, and in the last two of which epidemics had broken out, severe and sudden, "without there being any question of other distribution than through the sewers," he adds: "Towns with

larger sewers have not appeared to have the same suddenness of outbreak when spread by means of sewer air has been in question. In them the evil influence of sewer infection is more gradually manifested, as might be expected from the different physical circumstances of the two kinds of sewers." After remarking upon the greater relative displacement of air in small sewers by any sudden increase of flow, he further says: "It is plain that means of ventilation are wanted more numerously in proportion as the displacement of air may be local and sudden. For any want of freedom of current and lack of proper exit-means for displaced air *tells for more* in small than in large sewers." He remarks also upon the great danger, as shown by the experience of Croydon, of connecting houses with the sewers without the intervention of a trap, which is the Memphis plan, and by which the air of the sewers is brought directly into the house, or "laid on," as Dr. Buchanan expresses it, and he recommends a disconnecting trap in all cases, as does nearly every other sanitary engineer with the exception of Col. Waring.

From this testimony then, which is of the very highest order, it appears that the separate system, and particularly Colonel Waring's form of it, is not "universally admitted to be healthy and safe," but is tainted with grave suspicion; that in point of fact it involves greater dangers and requires greater care than does the combined system.

But Mr. Chanute also adduces some testimony which we must for a moment examine. Of this the first item is, that on his return to Kansas City, after the persistent disregard of his advice of two years before and the construction of many miles of the kind of sewers he had condemned, he finds upon inquiry "a general impression that the city is not healthy as it was in the early days of its history." Some of the leading physicians have also informed him that "there has been an increase in zymotic diseases, and that they showed a marked difference in type from the same diseases as they existed in the days before sewers." On the other hand he adds, with great fairness, what ought usually to be added in regard to "general impressions" of this sort, "that in few cases only have they been traced directly to the sewers or to defective plumbing. Other physicians again, while admitting an increase in zymotic diseases, attribute it to the increase of population, or to the turning up of the soil while carrying on public improvements in various parts of the city." To all of which I think nothing more need be added. Mr. Chanute himself seems to be of the same opinion, and admits that he "must abstain now from making a positive statement upon this branch of the case."

The next testimony is that of the people of Memphis, who have tried the Waring for now four years, and who, as Mr. Chanute tells us, pronounce it "a complete success." and are "thoroughly satisfied with the result."

Now, as far as it goes, this testimony is certainly valid and to the point, but a consideration of some other facts will, I think, show that it is not much more conclusive than the "general impression" already cited. It might, perhaps, be a sufficient reply to place in evidence the experience of the city of St. Louis, which for now more than thirty years has tried the combined system, and in which the mortality rate is now 21 as compared with 36 per 1,000 in the decade preceding the construc-

tion of sewers, after excluding the cholera year 1849, in which the rate was 106. Of course, it goes without saying that in view of these facts the community is, if possible, more than "thoroughly satisfied with the result."

But as the question is not so much what the people of Memphis or any other city think as what they ought to think, let us for a moment consider the facts of this much cited case.

In the decade 1870 to 1880 Memphis had experienced three epidemics of yellow fever, the first in 1873, the next in 1878, followed by another in 1879, that of 1878 being one of the most terrible in modern history. The highest sanitary authority, the National Board of Health, after a most careful survey of the situation, had pronounced the immediate and total abandonment and obliteration of the cess-pool system of the city to be one of the essential conditions of its future safety. With a population of but little more than 30,000 [being exactly 30,659 on Jan. 1, 1880, by the National Board of Health census], with its finances in such a hopeless condition that it had sought refuge from its creditors by surrendering its franchise as a city and becoming simply a "taxing district," the question was not what system of sewerage is in the long run best for a large city, but what system will abolish the cess-pools of Memphis in the shortest time and for the smallest amount of money. To this question the committee of the National Board of Health, of which Colonel Waring was a member, had answered by recommending the separate system, and under the circumstances its adoption by the city was the only thing possible.

The execution of this plan, having been put into the hands of Col. Waring, was carried out with much energy, but in several important respects the work done there does not commend itself as a precedent. The pipes were laid, as he himself says, with an "utter disregard of alignment" and only six feet deep, so that the drainage of cellars is impossible. The mains were so badly proportioned to their work that some of them run "over full all the time," and several of them must be either enlarged or duplicated. Manholes were almost entirely omitted, although the experience of Memphis since, and of all the world before, has shown them to be necessary, whether on small sewers or large ones. In order to flush the main sewers a large number of Field's automatic flush tanks, on which Col. Waring controlled the patent, were put in;* but by the total exclusion of rain-water any flushing of the house drains, where flushing is needed most, is rendered nearly impossible. Then, too, the mode adopted of ventilating the sewers through the house drains is, as we have seen, one which, after trial, has been condemned by Dr. Buchanan and sanitary engineers generally as dangerous to the public health.

But, notwithstanding all their defects, the new sewers, with occasional obstructions, have continued to run, the cess-pits have been abolished, and the yellow fever has not come nearer to the city than three hundred

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*Since this paper was put in type I have been informed by Col. Waring that the regular royalty on the flush tanks was in this case largely reduced, and his own share of it wholly remitted to the city. The number of flush tanks in use Jan. 1, 1884, on 39.1 miles of sewers, was 186, or one for every 1,110 feet of sewer.

miles. Let no one, however, jump to the conclusion that Memphis is happy above other cities which are not sewered on the Waring system, for such is not the fact. As the result of a most careful study of the records, Dr. Reilly, Inspector of the National Board of Health, found that in the five years preceding the year 1880, in which the new sewers were constructed, the average death rate of Mempbis, excluding mortality from yellow fever, was 34 per 1,000. Since the construction of sewers. we have mortality reports for 1881, 1882, and 1883, in which the total deaths were 1,471, 1,121, and 1,403. Computing the population from the census of June 1, 1880, on the basis of four per cent. increase per annum* (which is the rate used for St. Louis, and is higher than the census figures would allow for Memphis), we find the death rates for these years to have been 42.1, 30.9 and 37.1, respectively, or an average rate of 36.7 per 1,000 as against 34 during the preceding five years in Memphis, and 21 during the last four years in St. Louis. Now, without caring to press these figures to the conclusion that the new sewers have been of no benefit to the public health, or in fact to any definite conclusion whatever, it is very clear that they do not tend to show any sanitary superiority of small sewers over large ones, and the advocates of the Memphis system would, I think, do well, for the present, to adopt the words of Mr. Chanute, and "abstain now from making any positive statement upon this branch of the subject."

As a result of this discussion we may, I think, very safely conclude that if sewers for storm water be needed in Kansas City, as they will be if the city continues to grow, there is no sanitary reason for constructing another system for the purposes of house drainage. Or, to use Mr. Chanute's own illustration, if we have cut a hole for the cat we need not make another for the kitten, Col. Waring to the contrary notwithstanding.

Of course there may, and no doubt will, arise cases where, for special reasons, such as the extension of water pipe into a sparsely peopled district or suburb, a system of small-pipe sewers may be the only available means of preserving the soil from saturation with filth. Such cases exist in St. Louis and no doubt exist in every growing city, and the remedy should be promptly applied. But even here the example of Memphis offers more to be avoided than to be imitated. The pipes should always be placed deep enough to drain the cellars. They should be laid in straight lines and provided at the changes of line or grade with properly ventilated manholes or lampholes, and should not be connected with the houses except through a trap. The admission or exclusion or rainwater should be decided in accordance with the circumstances of each case. If it can possibly be disposed of by overflows

* The figures used for the population are :

June 1st, 1880	33,593–U. S. census.
" " 1881	34,937
" " 1882	36,334
" " 1883	37,787

To bring the average death rate since the construction of sewers down to the former rate of 34 per 1,000 would require us to assume that the population had increased at the wholly improbable rate of eight per cent. per annum, or one which would double the population every nine years.

or otherwise, the admission of roof water is of very great advantage to the house drains. As regards flushing the main sewers, it is more than probable that with the steep grades and muddy water of Kansas City, a manhole with a flushing gate will be better than any form of automatic flush tank. In fact, the pipes will probably be found, as in like cases in St. Louis, to keep themselves perfectly clean without any artificial flushing whatever.

It is true that systems of this kind, except where they lie at the extreme upper limit of a water shed, will, in the great majority of cases, be in time superseded by the storm-water system, and there will be a loss in money. But nothing will have been spent in royalties, and there will be a saving in that which gives money its only value, the health and life of its possessors.

DISCUSSION AND REPLY.*

By O. Chanute, Member American Society of Civil Engineers.

I am very much obliged to Mr. Moore for the honor which he has done me in criticising my lecture upon the Sewerage of Kansas City.

At the very outset of that lecture I requested that it should be critically received, so that whatever was sound might stand, and whatever was erroneous might be eliminated, and I am gratified that Mr. Moore has been at so much pains to muster adverse arguments, data and authorities on the subject. This cannot but promote the object which we both have in view, of getting at the truth, as to what it is actually best for the people of Kansas City to do about their sewerage.

I must say, however, that my opinion has not been changed, and that the reasons which Mr. Moore has given, do not seem to me to be good reasons why the separate system should not now be adopted for the greater part of that portion of Kansas City as yet unprovided with sewers.

He first assumes that storm-water will prove such a nuisance in all parts of the city that storm-water sewers should be provided everywhere to abate it.

This conclusion is, I think, erroneous and unsound for a city which is being built, and must remain in so promiscuous and scattered a condition as Kansas City. Instead of growing up a compactly built town, gradually extending itself into the suburbs, like St. Louis, for instance, it resembles rather an agglomeration of several towns, separated by precipitous bluffs, and has a curiously complicated and broken topography.

Here and there are rows of stores and dwellings with many reaches of vacant lots and rough ground between them, and while only about one-seventh of its area is as yet sewered (upon the combined system), this comprises pretty well the business portion of the city.

If, therefore, the combined system be adhered to, its great cost, together with the prevailing uncertainty about the future grades of the streets, which are being constantly changed, must so far delay the construction

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* Delivered before the St. Louis Engineers' Club, March 12th, 1884, and reduced to writing at the request of the club.

of sewers as to leave undrained for a long time many portions of the city, where the soil is now being polluted and poisoned by cesspools, as was that of Memphis.

If, however, the separate system be now adopted, it can by reason of its lesser cost be at once extended where needed, and when storm sewers become required, (for I do not claim that none will be needed) they can be confined to those short sections in which storm water positively proves a nuisance.

I therefore deny Mr. Moore's assumption that if storm sewers are ever to be required they might as well be put in first as last. That we should go on with expensive plans now, for fear we may have to resort to them some time hence. This may seem wise to the men who plan the works, but the people who have to pay for them may entertain a different opinion.

Not only do I deny the present assumed necessity, but I also deny that the future necessity for storm water sewers in Kansas City will be anything like so great as Mr. Moore has assumed. He has not sufficiently considered the fact that if rain water is not polluted with sewage the future storm sewers may be confined to those short sections where serious annoyance occurs; that these will be at shallow depths and that the water may again be carried on the surface where the situation admits of it, while with the combined system the foul mixture of sewage and rain water must be carried under ground, all the way to a final outlet and at the full depth required to drain the cellars.

I think the experience of engineers in cities having the combined system is misleading. They deal with the double requirement of carrying the foul house sewage under ground and of abating an occasional nuisance, and while the property owners might be quite content to have an occasional rivulet in front of their premises or flooded gutter at the street crossing; would prefer it in fact, as do the citizens of Baltimore, for the sake of the resulting clean streets were no combined sewer at hand to tempt them, the engineers fail to realize that storm sewers are really not needed at all points.

It seems to me that this question as to the future necessity of storm water sewers is best tested by the practical experience of towns with the separate system. A number of cities have been so sewered in England and in this country, and thus far not one of them, to my knowledge, has been led to carry out a second system of storm sewers coextensive with the first sewage system, as Mr. Moore would lead us to believe will be the case.

But Mr. Moore says that the experience of these cities does not apply, because they are small. That, while surface channels or small sewers may be tolerated in small towns, large cities require large sewers. This argument is an old acquaintance, which has repeatedly done service in opposition to the separate system. In point of fact there is little or no force to it, and it does not apply to Kansas City, because its topography makes it, what it must remain, an agglomeration of several towns, and because, after all, plans have to be made appropriate to the requirements of each case. The proper treatment will differ even in various parts of the same city, and I may as well confess here that on the flat bottom

lands of East and West Kansas City I would advise probably the combined system, while for the sharply undulating city on the hill, the portion which we are generally thinking of when we speak of Kansas City, I advise the separate system.

This portion of the town site much resembles that of Baltimore in the steepness and short drainage area of its streets ; and Baltimore, with its 322,000 inhabitants, has but 11 miles of storm sewers, while St. Louis, wlth 360,000 people, has 318 miles of combined sewers ; and Mr. C. H. Latrobe, in his report to the Mayor and City Council of Baltimore (August, 1881) says : "It is probable that a few more sewers, added to what we already have, will effectually accommodate the storm water where it is inconvenient, and leave us unhampered to construct the other branch of the separate system, which shall take care of the sewage proper, relieve our gutters from slops and refuse of all kinds, and enable us to get rid of the cesspools."

Now, notwithstanding its small amount of sewers, Baltimore has notoriously clean streets (which is more than can be said of St. Louis), and I even fancy that the streets of Kansas City which are sewered are not now as clean as they were in the old days, when the storm waters swept over them.

Kansas City has now (December 31, 1883,) some 21½ miles of combined sewers, which have cost $445,748, or say $20,727 per mile, and I estimated in my lecture that perhaps $150,000 more might be required for storm water sewers proper if the separate system be adopted now, while I stated that even if this amount were doubled there would still be a notable economy over the continance of the combined system. So far, therefore, from assuming that surface removal of storm water is *all* that is required, I think that I made a liberal provision for the abatement of the storm water nuisance, which my acquaintance with the town site of Kansas City, now dating back some 17 years, leads me to believe will not be one-tenth as great as Mr. Moore has represented.

I think, therefore, that the wise plan for Kansas City now to adopt is first to provide for the drainage of the cesspools ; to stop the further pollution of the soil, and to take up the disposal of storm waters only so fast as nuisance arises, especially as they can be confined to those short lengths where serious annoyance does occur, and then be placed at shallow depths, say 2 to 5 feet, instead of being carried, as now, from 10 to 16 feet under ground, to drain the cellars in the same set of pipes as the house sewage.

For this reason I also dissent from Mr. Moore's second assumption "that as storm water sewers will be a necessity, it is certainly cheaper to use them for house drainage than to construct another system for that purpose."

He leaves the latter dictum entirely unsupported by estimates or figures, and so far as I have been able to obtain the latter they point just the other way.

For instance, the cost of the combined system in St. Louis has been $30,146 a mile. In Brooklyn, New York, it has been $25,600 a mile, and the cleaning costs $133 a mile yearly. In Providence, Rhode Island, the first cost has been $34,550 a mile, and the cleaning costs $282 a mile

annually, while in Memphis the cost has been $6,875 a mile, and the sewers are cleaned and repaired at a cost of about $70 a mile a year.

When Memphis, fever stricken and ruined, turned to sanitary engineers for advice, the sewer builders of the combined school proposed several plans varying in cost from $800,000 to over $2,225,000, depending upon the amount of storm water to be accommodated. Mr. Waring, however, put in about 18 miles on the separate system in 1880 at a cost of $137,000, and the city authorities have since added about 22 miles more, at an additional cost of about $138,000, thus making a total cost of $275,000 for some 40 miles of sewers at the close of 1883, which are said to drain even more territory than was contemplated in the estimate for combined sewers. No storm water sewers have yet been added, probably because the storm water, even in that moist climate, has not yet proved to be the terrible nuisance that Mr. Moore would have us imagine. When they are needed it is probable that they will be put in at those points where they are required, for a good deal less than the difference between $275,000 and $2,225,000.

But we have evidence nearer at home. The separate system of Leavenworth, Kansas, now approaching completion, has cost less than $10,000 a mile, or, to give it in the way in which we pay our sewer assessments, it has cost 44½ cents a square (of 100 square feet) for the house drainage proper, and, including the outlets, only 65½ cents a square; while the combined system of Kansas City has cost to Dec. 31, 1883, some $2.10 a square. I submit that the resulting difference of $1.44½ a square will pay for a good deal of storm sewers, which, be it remembered, will be shallow, while the Leavenworth pipes for sewage proper are from 7 to 27½ feet under ground.

I may mention here, in passing, that Mr. Latrobe's estimate for a separate system for Baltimore also shows a cost of about $10,000 a mile, and that this may fairly be assumed as the probable cost at Kansas City for the house sewage proper.

Now, the cost in the latter city for the combined system has thus far been $20,727 per mile, and 7.16 miles were built last year. Let us suppose (to confine ourselves to a very brief period of time) that the city goes on at the same rate for only five years more. It will, according to the above data, still spend some $350,000 more for the combined sewers than if it now inaugurates a separate system.

The people of Kansas City know just how much of a nuisance the storm water is now in the unsewered portions of their city. It is for them to determine whether they are willing to spend some $70,000 a year to abate it during the next five years.

But as a reason why this economy cannot be realized Mr. Moore says that "the map shows the shortest slope in the direction of the streets, from the crest of the ridge to the river to be 3,500 feet. That on such grades storm water in the gutters becomes a serious matter after it has run five or six hundred feet. Beyond that distance it becomes a raging torrent, sweeping everything before it, and rendering the cross-streets for the time being impassable. I should say that a thousand feet, or less than one third of the shortest slope, was the limit of endurance, leaving the other and lower two-thirds to be in any event provided for by sewers."

Now it is a peculiarity of the situation at Kansas City that the lower third of this slope is practically through waste land, at present, at least. The business and residence portion of Kansas City is built upon a bluff about 200 feet high bordering upon the river. A mistake was made in the early laying out of the town site in attempting to make it conform to that of St. Louis and other river towns, by cutting a number of very steep streets from the river inland. These cuts made great gulches from 80 to 100 feet deep, on which few or no houses have been built. The river front of the town, therefore, instead of being covered with residences (like Columbia Heights, in Brooklyn), is occupied by brick yards, which are nibbling at the hills, and as even these are 40 or 50 feet above the bottom of the gulches, the raging torrents, which Mr. Moore depicts as tearing down the gutters, create no particular nuisance.

It is a further peculiarity of the situation that Mr. Moore informs me that he has measured this 3,500 feet slope, along the line of Broadway, from Twelfth street to the river. Now the property which I own is situated precisely on this street. The first piece is near Ninth street, just about 1,000 feet below Twelfth street (Mr. Moore's "limit of endurance"), and the last piece is at Seventh street, about 1,500 feet below the "crest of the ridge." I have not yet found in some sixteen years' ownership the storm water to be the unendurable nuisance that Mr. Moore imagines, and this leads me to disbelieve his assumption as to the rest of the city.

Such is the difference between theory and local experience. I know how it is myself, and if anybody is to be ruined by the storm water nuisance on that street, in case the separate system be adopted, I shall be one of those to suffer. I am willing to chance it, and inasmuch (as Mr. Moore judiciously points out) "the rains will still fall on the streets," I prefer, like the citizens of Baltimore, that the storm water, instead of trickling a faint slimy streamlet into the corner catch basin, shall come down with sufficient volume and force to wash the dirt and rubbish (including straw) which may accumulate in front of my premises, down to my brick-making neighbors.

But as Mr. Moore rightly says, the sanitary question is of vastly greater importance than the saving in cost. Upon this question he seems quietly to have ignored all that has been said on the subject by sanitarians, both in this country and in Europe, and to my mind his argument simply proves that the combined system is better than no sewers at all.

The evidence which I chiefly quoted at the time of my visit to Kansas City two years ago was the following extract from the report to the Board of Health of the State of New York, on sewerage: and much as I dislike to quote the same thing twice, even to a different audience, I will take up your time by reading a part of it.

"*The Combined System of Sewerage.*—This system of sewerage can only be economically used where it is necessary to provide, even at large expense, for carrying off the storm water underground. The storm water falling per hour in violent rains over an acre of closely built up city land is nearly fifty times the amount of the waste water and sewage produced per hour on the same area. The sewage is, therefore, ordinarily a mere trickling thread in the bottom of a sewer large enough to carry off great bodies of storm water. In time of rain the sewer will be nearly or quite

full of dilute sewage, which is absorbed by the bricks, and leaves a coating on them as the water falls. The powerfully flowing stream of storm-water on subsiding, deposits silt in the bottom of the sewer, which obstructs the flow of sewage, giving it time to decompose. Foul gases are then emitted, and it has been popularly assumed that these gases, called 'sewer-gas,' are the cause of disease.

"Physicians are agreed upon the fact that air from sewers passing into a dwelling is very likely to produce serious disease. That this illness is due to a *gas* from decomposing sewage is a mere assumption unsupported by proof. But the hypothesis was hastily adopted by engineers, who naturally inferred that the healthfulness of large sewers would be secured if they could only drive out or sufficiently dilute this gas by ventilating the sewer, or prevent its formation by keeping the stream of sewage flowing uninterruptedly. The discussion of the subject by Mr. Eliot C. Clarke, in the Massachusetts Board of Health report,* and the opinion of other engineers who favor large sewers, seem to be based on this idea.

"It is time, therefore, to call attention to the fact that *no such gas as 'sewer-gas'* exists, and that *there is absolutely no proof that the diseases which attend the admission of sewer air into a dwelling are produced by gases.* On the contrary the whole tendency of modern investigation is to show that the zymotic diseases are produced by *bacteria*, whose germs are developed under favorable conditions. It is well known that the most favorable conditions for the growth of these low organisms are heat, moisture, darkness and the *presence of ammonia.* The damp walls of sewers present, therefore, all the requirements for a most flourishing growth of bacteria, whose germs may float off on the sewer air and be carried into dwellings by mechanical action, as dust is borne on any air current.

"It is, therefore, most probable that sewer air brings the germs of disease into dwellings as dust is blown into the window. The foul gases of decomposition may or may not be present. The fatal power over life lies, probably, in the little plant-seed, odorless and invisible, floating upon the sewer air.

"Large sewers are, then, plantations for the propagation of deadly organisms, the moist, porous walls forming most favorable soil, the ammonia of sewage supplying the manure essential to full development, and the warm, damp air stimulating to the utmost all processes of growth.

"The occasional flushing of sewers, while it may clear out silt and accumulated filth, and thus decrease the amount of heat and ammonia from decomposition, can never prevent the growth of bacteria on the sewer walls, nor will ventilation prove efficient. Every device of engineering has been exhausted to keep large sewers clean and well ventilated, but the air from them is still deadly. Experience, therefore, teaches that there is some radical defect in the system of large or combined sewers, while modern investigations of the origin of zymotic diseases and the mode of growth of bacteria seem to show that sewer walls are almost

* Second Report Mass. State Board, New Series, 1880.

ideal hot-beds for the production of fatal organic germs. Perfect plumbing may prevent sewer air from entering dwellings, but perfect plumbing will always be the rare exception.

"In view of these facts I am forced to conclude that from a sanitary point of view the combined system of sewerage is a failure.

"I visited in London the sanitary department of the Local Government Board which has general supervision of the sanitary affairs of England. The Chief Engineer, Mr. Robert Rawlinson, C. E., and the principal medical inspectors, Dr. Ballard and Mr. Radcliffe, are perfectly agreed that the combined system of sewers is radically defective from a sanitary point of view. In this opinion Dr. Richardson and other prominent sanitarians concurred. At the meeting of the British Association for the Advancement of Science, in York, the leading civil engineers whom I met had abandoned their belief in the 'combined systems' of sewers, being convinced that it could not be made healthful.

"While all were agreed as to the failure of the 'combined system' some of the medical men favor the general introduction of the 'pail system' of Manchester of 'dry removal' of the excreta in tubs, and the use of sewers entirely disconnected from dwellings, to carry off only waste and storm-water; while Mr. Rawlinson and other engineers advocated water carriage by the 'separate system.'"

There seems to be no fact better established than that the large sewers required for occasional floods in the combined system do give rise under certain circumstances to exhalations which produce disease. Confirmatory facts must be in possession of nearly all of you, and I did not dwell on the subject in my lecture because the matter seems to be well understood at Kansas City, especially by the physicians, who had already expressed some very positive opinions in published interviews, which more than supported the statements which I made.

Even now that Mr. Moore questions those statements, I will not take up time to accumulate more evidence on this branch of the subject, because after all, the main question is whether the separate system, as improved and carried out at Memphis is, or is not safer, in a sanitary point of view, than the combined system.

Whoever has made an excursion in a combined sewer in time of drought, and observed the slime which covers the walls, the fungous growth to which it gives rise, and the feeble trickling stream meandering around masses of putrefying matter, while breathing the foul air which it generates, will not require much argument as to the offensiveness of large sewers.

But Mr. Moore says "there can be no difference in the amounts evolved from the same quantity of sewage in different sewers," for the reason that, as the length and grade will remain the same, there will be "no material difference in the two cases, either in the velocity of flow or in the quantity of the products of decomposition."

Here we discover the cause for his erroneous conclusion. He has failed to realize that the separate system is daily flushed to nearly its full capacity, while the combined system is only flushed in time of rains. He ignores the most important and meritorious feature first introduced at Memphis, the daily flushing by means of automatic tanks, which com-

pletely negatives his assumption that there will be no "difference in the time of exposure."

The volume of gases in a sewer is the result of the decomposition of *deposited or retained matters*, while the amount evolved from the active flow of fresh sewage is trifling ; so that the quantity is regulated, not by the amount of flowing sewage, but by the amount of stagnation and deposit. What this may produce in droughty Kansas City, where I have known three spring months to pass without one drop of rain (it made up for it afterward by falling seven measured inches in one night), will probably appear if there be such a drought again.

I am willing to grant that were there no efficient flushing the house sewage arrested in the sewers, or smearing their surfaces, and dependent upon an occasional rain storm for its removal, would prove even more dangerous in small pipes than in large ones. The case is entirely changed when that sewage is at once carried to its final outlet by the water from the flushing tanks, when in fact we insure a private rain storm once or twice a day at the head of every sewer, and so produce a velocity of flow of 2.6 feet per second, as measured in the mains at Memphis.

The instance, therefore, of the outbreak of typhoid fever at Croydon in 1875, proves nothing against the use of small pipes, unless it can be shown that the flushing arrangements spoken of by Mr. Moore as having a close resemblance to the Waring system, were as efficient as those carried out at Memphis in 1880. To my question as to what these arrangements were, Mr. Moore answers that he does not know exactly, but believes there was some provision by which the water from the town mains could be used. I suppose this depended upon occasional manual working, and unless it is shown that the water was used in flushing quantities once a day I fail to see the resemblance. To my thinking the sanitary advantage of the separate system lies not in the smallness of the pipes, but in this, that the pipes being small, it then becomes practicable thoroughly to flush them without undue waste of water.

In answer to my further question, Mr. Moore admits that the combined system would certainly be safer if it were daily flushed to ½ to ½ of the maximum capacity of the sewers, as is found to be the case at Memphis ; but of course we cannot spare sufficient water to flush daily sewers from 5 to 10 feet in diameter, such as are required in some parts of the combined system.

Now let us examine Mr. Moore's criticisms as to the Memphis system proper. He makes the following points :

1st. "That the houses are connected with the sewers without the intervention of a trap."

I think that in this Mr. Moore is mistaken, and that this may account for much of his opposition to the Memphis system. As I understand it the main house pipe does connect with the sewer without a trap, but every outlet for waste is separately trapped. That is to say, that the house main, down which all refuse flows, has no downward U bend near the sewer, in which a portion of the water shall remain after every discharge to form a liquid seal against the intrusion of sewer air. It is instead carried up the full size (4 inches) above the roof of the house, and left open, in order to ventilate the sewers, but every water-closet, kitchen-sink, bath-tub and

waste-sink connects with the 4-inch pipe with a trapped connection of its own.

The air of the sewers is therefore not " laid on " to the houses, and Dr. Buchanan's testimony does not apply to the Waring system, of which, of course, he could know nothing, while the only theory upon which Mr. Moore can claim that sewer air will gain admittance, is that separate trapped connections are more likely to get out of working order than one main trap next to the sewer.

If this should prove to be the case, if experience at Memphis or elsewhere, should determine that it is better to have one main trap to the house main, I do not see why this may not be done at Kansas City.

2d. The sewers at Memphis are only 6 feet deep, and do not drain the cellars.

I believe that in point of fact there are few or no cellars in Memphis, and this may account for this shallow depth. At Leavenworth, however, where there are cellars, the district sewers are from 10 to 16½ feet deep, and I fancy that Col. Waring's patent will not prevent putting them to the same depth at Kansas City.

3d. The sewers at Memphis were laid crooked.

This is sad if true, but I think I may safely promise on behalf of the people of Kansas City that if Mr. Moore will allow them to adopt a separate system of sewers, they will lay the pipes as straight as ever they can.

4th. The mains were made too small.

Taught by experience, they will be made larger. It is simply a question of carrying off the water from the flush tanks, and from the general consumption of the city.

5th. Man holes were omitted.

This, I believe, was an engineering mistake, committed from motives of economy. In fact, when Col. Waring presented a paper upon the Memphis sewers before the Sanitary Institute of Great Britain, the only criticism made by the members present, gentlemen thoroughly familiar with both the combined and separate systems as carried out in England, was that manholes should not have been omitted. I understand that 44 of them have been put in at Memphis by the city authorities, and that they are being put in at Leavenworth. I should advise the people of Kansas City to do the same.

6th. The flush-tanks and system are patented, and there is a royalty to pay for their use.

This, I imagine, is the real and great demerit in the Memphis system, the one which has caused it to be so severely criticised, and has much delayed its adoption.

Engineers as a rule, myself among the number, do not like to use patented plans. They prefer to make their designs for themselves, to adapt them to each special case by adding, ommitting or altering such features as they desire, untrammelled by a patentee ; and they resent, as a slur upon their capacity, the intrusion of a cut and dried plan. Others, again, think that Col. Waring should not have patented the system which bears his name, because if it really possesses the great sanitary and economical merits which are claimed for it, no obstacle, such as a

patented monopoly, should be interposed to its early and general adoption.

Mr. Moore makes what seems to me a rather unworthy reference to Col. Waring, who is, so far as I know, an honest man, in saying: "Automatic flush tanks of the kind on which Col. Waring controls the patent, were put in liberally." I am informed by Col. Waring that the use of all the flush tanks that might ever be required in connection with the sewerage of Memphis, was licensed for a round sum of $1,000. That of this his own proportion was $250, and that this $250 was credited to the authorities of Memphis, as a part of the payment of his professional fee.

Now, the fact that there are patents outstanding upon the system or some of its parts does not seem to me a good reason to condemn the separate plan. I have not, therefore, thus far troubled myself about the patents, and in fact have never seen them. The first inquiry to be made is whether the separate system, as perfected by the addition of flushing tanks, is the best for Kansas City now to follow. If this should be decided in the affirmative the next question will be whether Col. Waring's patent is valid, and if so, what is the best bargain that can be made with him.

It is very evident we have not got beyond the first inquiry as yet, as the Mayor's proposal, made some months ago, for a committee of investigation has not yet been acted upon. In the meanwhile there are many engineers in various parts of the country who are even now devising different forms of flush tanks and different methods of flushing separate sewers regularly, and it is not impossible that some means shall be found of superseding or avoiding Col. Waring's patents. But even if this cannot be none, the charge will not be an onerous one in proportion to the saving effected. At Leavenworth, for instance, I am informed that the royalties on the work now in progress will be about $1,600, while the saving effected, if we assume that the combined system would have cost there the same per square as at Kansas City, would amount to about $90,000.

It was stated in the discussion which followed my lecture at Kansas City that, were the separate system to be adopted for such unsewered portions of that city as need early relief, the royalties would amount to some $5,000. I think myself that this estimate is entirely too low; but suppose we quadruple it, and call it $20,000. If it enables us to save spending $350,000 during the next five years, it will still be a notable economy, always assuming, of course, that nobody shall in the meantime improve upon Col. Waring's system, and forbear from patenting the improvement.

These are, I believe, all the objections raised by Mr. Moore to the Memphis system. They are chiefly questions of details which may be modified. While there is therefore no doubt in my mind that the combined system is much preferable to no system at all, I submit that the main question is, whether, under the circumstances, it is not preferable for the people of Kansas City, from a sanitary and economical point of view, now to adopt the separate system as improved by the addition of flush tanks, instead of going on with the combined system; whether

they are not likely to be as well satisfied with it as are the people of Memphis.

But, says Mr. Moore, if the people of Memphis are satisfied with their separate system (which has cost $6,875 a mile), so are the people of St. Louis satisfied with their combined system (which has cost $30,146 a mile), and so he leads us to infer that one satisfaction offsets the other. Except:—that the people of Memphis ought not to be so much satisfied after all, because while St. Louis has a death rate of 21 per 1,000, the Memphis death rate was 34 per 1,000 in the five years preceding 1880, *omitting yellow fever*, and was, as he figures it, 42.1 in 1881; 30.9 in 1882, and 37.1 in 1883.

Now, in the first place, it seems to me that inasmuch as the sewers of Memphis were especially intended to drain the cess-pools, which formed the hot-bed of yellow fever, a comparison which begins by omitting deaths from this disease (about 5,000 in 1878, out of a population of 40,000, and some 500 in 1879, out of a population reduced to 13,000), is open to some question. This method of reasoning might be extended to the conclusion, that the sewers actually increased the death rate, from an average of 34 in the preceeding five years, to an amount of 42.1 in the year next succeeding their construction.

But in the second place, I find in the fifth annual report of Dr. G. B. Thornton, President of the Board of Health of Memphis, for the year 1883, the following statements, which seem at strange variance with the facts as alleged by Mr. Moore:

"The increased number of deaths over that of last year is clearly due to an increase of population.

"In computing the death rate per one thousand, I have adopted as the best estimate of the population at my command, the figures of Shole's Directory, compiled in November, 1883. According to it, there are 12,785 white and 5,025 colored names, total 17,810, which multiplied by 3½—the smallest multiple taken in estimating population by a business directory—gives a total population of 62,335. Assuming 35½ per cent. of the total population to be colored, it would give a white death rate of 15.19 per 1,000, and colored rate of 35.83—total, 22.50.

"The report for 1882 showed by a similar estimate of total population a death rate of 24.36. . . . .

"Of the 1,403 total deaths for the year 1883, 265 were known to be non-residents, or people who were in the city less than one year, their term of residence varying from a few days to a few months. Many of them were employés of contractors on the railroads, and work of like character near the city. The total deaths in the city hospital for the year were 215, a large majority of which were non-residents, who came to the city seeking hospital treatment."

Dr. Thornton then renews his recommendations of previous years, concerning the amelioration of the water supply which is thought to be contaminated with sewage, the extension of the sewer system, and the draining of Bayou Gayoso, a low-lying district as yet unsewered, where many poor people live, and which is so foul and frequently overflowed, that it is thought that Memphis will not really be safe from a recurrence of yellow fever until it is reclaimed. He winds up his report thus:

"In conclusion I will state that the three essentials to the perfection of the sanitary work of Memphis are: The completion of the sewer system as originally designed, the substitution of Mississippi for Wolf River water, and the treatment of Bayou Gayoso as recommended in Fourth Annual Report. Any other detail connected with the work, however important it may be considered, is but secondary compared with these."

The discrepancy between the figures of Dr. Thornton, and those of Mr. Moore, seems to arise from the fact that the former has estimated the population from his local knowledge, and from the directory, while the latter has estimated that the population increased four per cent per annum, upon the assumption that Memphis ought not to grow any faster than St. Louis. Applied to Kansas City this method of computation would produce strange statistics, but we will assume that the truth as to the death rate lies somewhere between the figures of Mr. Moore and those of Dr. Thornton.

While not disposed any more than Mr. Moore to draw any very rigid conclusions from vital statistics showing such discrepancies and covering so short a period of time, it seems to me that the figures point just the other way than Mr. Moore intends.

What are the facts? The people of Memphis had gone on year after year polluting their soil with cess-pools, just as the people of Kansas City are doing to-day. They had prepared a hot-bed for the development and retention of yellow fever and other diseases, and when the scourge struck them they could not undo in a day the mischief accumulated in years. They did what they could, built 18 miles of sewers and drained part of the ground in 1880, with the gratifying result that the epidemic did not return, but the death rate was still, we will assume in 1881, 42.1 per 1,000, instead of the preceding average of 34, omitting yellow fever. They went on, however, and built more sewers, while those of the previous year continued to drain the ground, and in 1882 the death rate was 30.9, says Mr. Moore, or 24.3, says Dr. Thornton. In 1883 the rate was 37.1, if the population increased no faster than in St. Louis, or 22.5 per 1,000, if it grew as indicated by Dr. Thornton. I submit that this, upon the whole, allowing for accidental causes, seems a satisfactory improvement, particularly when we consider that when the National Board of Health was appealed to by Memphis in 1879 it made some nine or ten recommendations of essential sanitary reforms, of which the sewer system was one, and that the three essentials which Dr. Thornton again and again mentions in his reports yet remain to be executed.

Thus to the three issues, as made by Mr. Moore, I have attempted to make answer as follows:

1st. That storm-water sewers will be a necessity *every where* in Kansas City.

I say that Mr. Moore has greatly exaggerated both their advantage and necessity. That in consequence of the peculiarities of its town site, with the 21½ miles of storm-water (combined) sewers it has now, and say 15 miles more of storm-water (separate) sewers, which being at shallow depths, will probably not cost more than $150,000, Kansas City will probably abate all material nuisance from storm water.

2d. That the combined system will be cheaper than the separate system.

I say that he has not offered a particle of proof in support of this dictum; that we must judge of such matters by the actual results of experience, and that thus far the experience has been just the other way: that the results in many towns in England, and in Lenox, Cumberland Mills, Kalamazoo, Keene, Memphis and Leavenworth in this country, all indicate the separate system to be permanently the cheapest.

3d. That in a sanitary point of view, the combined system is as safe as the separate system.

I say that separate sewers, regularly flushed every day, and in which sewage is at once carried to an outlet with a rapid current, must in such a climate as that of Kansas City be safer than those which depend for their flushing upon an occasional rain-storm. That the data concerning the health of Croydon and Memphis, so laboriously stated, are neither pertinent nor is the reasoning correct; and that notwithstanding the flourish at the end about royalties, and the health and life of the people of Kansas City, I still believe that it will be judicious for them to adopt the separate system.

THE SYSTEMATIC DIVISION OF LAND.

A PRELIMINARY STUDY.

By Hosea Paul, Member of the Civil Engineers' Club of Cleveland.

[Read September 11, 1883.]

When new territory, especially if of considerable extent, is put into the market a systematic division is not only possible and practicable, but its advantages are so manifest that in modern times something of the sort is universally attempted with varying degrees of success. It is not difficult to hit upon some system that will be better than the haphazard selection that would proceed in the absence of any plan. It is so easy to accomplish this much that the subject is rarely a matter of thoughtful consideration or intelligent action, what is done being either in haste or left to incompetent hands, which circumstance may perhaps serve as an explanation why there are so few examples in laying out land either in country or city where the full capabilities of systematic division are fully brought out.

Systematic division might be defined to be the laying out of land into simple, regular geometrical figures, preferably rectangles of nearly uniform extent, and described by numbers recurring in regular order. It deals not only with the present, but to secure the best results it must in a measure forecast the future and provide for its needs; it must regulate yet not cramp the free play of individual action by giving grooves and channels to lessen friction.

Among the advantages to be derived from systematic division might be enumerated—

1. By its providing for present requirements parcels of suitable size ready and convenient for examination and occupancy without the delays caused by special selection, the consequent bargaining, and the necessity of special surveys.

2. By its recognizing the possibility of and providing for its future division into still smaller parcels.

3. Inasmuch as any regular figure will include land of varying worth, there will be a better opportunity of disposing of those portions of little value separately in connection with other parts which are more desirable. For instance, a rocky hillside. unsalable separately, may prove a useful addition to a lowland farm for pasturage, the growth of timber, or because of springs of water. In this way the seller can avoid the accumulation of undesirable remnants.

4. A regular division will better accommodate the uses to which land may be put either for the growing of crops, or erecting buildings upon. It aims to provide for "the greatest good of the greatest number."

5. Few advantages of regular division are so obvious, so striking and important as the increased ease and greater possibilities in the way of graphic representation.

6. This graphic representation is possible at the beginning often as fully as needed for many purposes without other surveys than those actually made in laying out the divisions.

7. The surveys may be mainly shown by maps covering a considerable number of the divisions and the necessary facts of direction and distance noted in the lines themselves. Such maps can be easily copied or published, and convey almost at a glance an amount of information that would otherwise occupy a large and usually widely scattered spaces in written records of deeds.

8. Simplicity of description. The number of the parcel being given, the length of lines, acres, etc., can be omitted as information shown by the map, and usually expressed in better terms than by words attempting to transcribe from it.

9. By means of the greater ease of graphic representation the burden of taxation can be more equitably adjusted : each owner's interest can be marked off and in this way none need be overlooked or forgotten.

10. Greater simplicity, uniformity and certainty in the work of the surveyor, the regular divisions being used as a means of correction, adjustment and verification.

Although something of a regular subdivision of land has been possible in the United States ever since its first occupation by Europeans, very little in this direction was attempted in early colonial history, probably because its advantages were not appreciated as in later times. The early settlers in New England in this respect did not advance much beyond English customs. Much of this country is rocky and broken, and that was first reclaimed from the wilderness that seemed best adapted for the plow, and the fields were consequently often of irregular outline, and the fashion of the times was to build stone walls after the English practice, not only for their permanence, but as a good way of ridding the fields of unwelcome bowlders. An inspection of village plans will show great irregularities, and to one accustomed to regular lots and rectangular crossing of streets such plans are a curiosity. Not only are the lot lines twisted about to an unnecessary extent. but the sides of the streets or highways are not always parallel to each other, or for that matter to anything else, but each side winds about regardless of its fellow.

In the State of New York there were formerly large holdings of a semi-feudal nature in several counties in the central part of the State. The patroons, as the holders of these large estates were called, leased out their land, refusing to sell. In the course of time the tenantry became dissatisfied and the landlords not yielding to their demands, the famous anti-rent agitation of 1840–46 was inaugurated, and though there were some agrarian outrages, the movement which in some countries might have amounted to an outbreak or insurrection against constituted authority took a political form and became a complete success, effectually breaking up such an unrepublican system. It is believed that the division of this territory is quite irregular.

One of the earliest examples of division by number on a large scale is that afforded by the Holland Land Company's large tract, which embraced several million acres of land in Western New York and Northwestern Pennsylvania. The name is derived from the fact that among those who, at various times during the progress of the revolutionary war, loaned money to the Continental Congress, were certain bankers in the old and wealthy Dutch city of Amsterdam. After the close of the war, being without other resources of repayment, this large territory was granted to a company composed of Harm Jom Huidekoper, Wilhelm Willink, and others. The divisions were termed tracts and designated by number. They usually contain about four or five hundred acres, being about a mile in length, a common form being a mile east and west by fifty chains north and south. The dimensions and directions seem, however, to be often varied without other apparent causes than those arising from imperfect surveys. The shapes of the tracts were sometimes made long and narrow to secure a frontage on some river, as is often done in the early French grants so common in Canada, and sometimes recognized and perpetuated in our public land surveys.

A very common practice in the wild and mountainous parts of Pennsylvania is to divide the land into tracts containing about a thousand acres. In some places, however, the State lands do not appear to have had any division at all. To encourage sale and settlement a sort of pre-emption or homestead right was given to whoever would settle and improve them. In due time an official surveyor would be called up to mark out a tract of such shape as might strike the settler's fancy, the main object being to inclose as much good land as possible, and leave out what seemed to be sterile and worthless.

Very often these claims were voluntarily abandoned before being paid for, a not uncommon thing in pioneer experience, and subsequent settlers ran new lines more in accordance with their own notions, but when once established they had to be followed by others. As may be imagined there was and still remains some confusion and overlapping of lines, and many nooks and corners were left out until the land became more valuable. Though these surveys were recorded, complete maps of such territory are very unusual, and some of the land is untaxed. The unit of measurement used is the perch, divided into tenths, and for every acre sold six per cent. is added or "thrown in," for instance, an hundred and six acres is described as one hundred acres, "together with

the usual allowance of six per cent. for roads." etc. Without this allowance it is called strict measure.

The Western Reserve of Ohio is a district which is comprised of the counties of Ashtabula, Trumbull, Mahoning, Lake, Geauga, Portage, Cuyahoga, Summit, Lorain, Medina, Erie and Huron, with a part of Ashland. About the beginning of this century this territory passed into the hands of the Connecticut Land Company, which was organized in 1795, with a capital of $1,200,000, there being 4,000 shares of $3,000 each. The purposes of the organization were merely temporary, inasmuch as instead of selling out the land, and dividing the proceeds, a partition of the same was at once instituted and carried into effect. Townships five miles square were laid out and numbered as ranges and towns, the ranges westward from the Pennsylvania line and the towns northward from the forty-first parallel of latitude, a system similar to that just previously introduced in the survey of the public lands adjoining. The township might be called the unit of the land company's division, the theory being that the townships were of equal value, inasmuch if by reason of an undue proportion of swampy or waste ground any one of them was deemed less valuable than the others, the adjustment was made, not by changing the price, but land in another township was added to it to bring it up to the average, the process being called equalizing, and those townships which were cut up into strips or parcels for such a purpose were called equalizing townships. The townships in this way having been brought to an average value, they were drawn by lot by the shareholders; and when this was done, the main object of the company was accomplished. The only surveys made by the company, therefore, were such as were required for this purpose, dividing the townships only where necessary for equalizing, and in such further division as was necessary to put the land into market, each proprietor acted as he saw fit. Generally speaking, without noting exceptions, if a township had a single proprietor it was divided into lots of from one to two hundred acres each. If there were several proprietors, the interest of each were called tracts, being designated by number, location as to north, south, east, or west, or taking a name from that of the owner, and their further divisions were known as lots. The survey of the townships by the Land Company was begun in 1797, and mainly finished in the course of four or five years. The division of the townships was begun immediately afterward, and very generally completed in the next ten years, or by 1815.

In some cases the owners of the tracts were in no haste to make sales, and consequently no division was made until a recent period. Other owners made sales from time to time without ever making a general survey or adopting a uniform plan.

In Summit County is the Portage Path, an ancient Indian trail about eight miles long connecting the waters of the Cuyahoga and the Tuscarawas. This trail passes near the city limits of Akron and crosses the water-shed between the St. Lawrence and Mississippi basins. At the beginning of this century it was a well-worn footpath through the forest, and as such it had been used by the Indians for a longer time than their traditions extended. It was so well-defined a highway that it was often

a dividing line between tribes, and for a number of years was by treaty the line of white supremacy. Probably every vestige of the trail itself has now disappeared, but by surveys its location is fairly established and marked, a necessary circumstance, inasmuch as this ancient trail of the savage is the line of individual ownership to-day.

That part of the Reserve embracing 500,000 acres covering Huron, Erie and parts of Ashland and Lorain counties, which is known as the Fire Lands, was granted to the inhabitants of New London and other towns in Connecticut who had sustained losses mainly by fire from the incursions of British troops during the revolutionary war. The loss of each individual having been determined, their interests were placed in the hands of trustees, who, following the example of the Connecticut Land Co. in the other part of the reserve, made an actual partition of the land and distributed it by lot, the partition, however, affording much smaller parcels. The first division was to cut the township into four quarters called sections, and numbered thus—

3	2
4	1

Each section would therefore contain about four thousand acres.

These were again subdivided into tracts and lots, and although no great uniformity was observed it had the advantage of being done by one authority and at one time, and what is of scarcely less consequence, very fair maps were made and the field notes, etc., generally preserved, and are now extant in a good state of preservation at the recorder's office of Huron County, the original limits of which formerly comprised the whole of the territory in question.

In this respect at least the trustees discharged their duties more faithfully than did the Connecticut Land Co., who were very remiss about getting up maps, having field notes kept, much less to preserve them; and as for the private surveys of townships, the taking of field notes and the compilation of maps was something that rarely received proper consideration, and sometimes none of any consequence were ever prepared, others have been lost and others are comparatively inaccessible to the public, being in the hands of private persons, who consider them little better than old rubbish that they are gradually getting rid of. The only systematic attempt to collect these maps and papers is that made by the Western Reserve Historical Society.

The execution of these early surveys was often very imperfect. The instruments used consisted of a two-rod iron chain and a small compass with a needle four or five inches long. Though the surveying party usually consisted of but four men, besides cooks, packmen, etc., the lines were run with great rapidity, sometimes ten or twelve miles a day. The surveyor would plant his Jacob staff in the ground, place the compass upon it level it with the needle (the only means afforded), then setting it in the desired direction, instead of sighting to a pole or staff, held by an assistant, would pick out such tree or other object ahead that was on or near the line of sight. A glance was usually sufficient, and then the surveyor would set out to the point observed to repeat the process, while the chainmen and the marker would follow after, the latter blazing such trees as were within his reach. Though the country was thickly wooded,

it was often comparatively free from undergrowth. It was often possible to see to a considerable distance, so that with a little care the lines could be made straight for some distance; and. the ground often being nearly level, could be measured with considerable accuracy. Such results were, however, rarely attained, and in many instances the imperfections are so great as to be best accounted for by the old traditions, that the whisky carried to prevent the bad effects of the bites of the then numerous rattlesnakes sometimes got into the heads of the whole party without improving the character of the work.

It is doubtful, taking into consideration the better general surface of the country, whether the actual work of the surveyor on the Western Reserve of Ohio was as well done as on the Holland Tract, and it is believed the records are not as perfect; but there was one great advance made, and that was in laying out regular numbered townships. Both were faulty from the absence of any well-defined plan of numbering tracts, and still more so in the neglect of the consideration of future subdivision.

One feature of the partition of the Reserve seems to be especially novel, and that was the ingenious method of equalization heretofore described, by which the units of division that had been determined upon were kept uniform. This principle could be adopted with advantage in a great variety of circumstances where land is partitioned off in severalty among those who have hitherto owned it in common. In attempting to adjust the different interests to the varying value of the land, regularity and symmetry of form are usually lost sight of, and thus a permanent disfigurement of outline may result from a merely temporary cause, that might be easily avoided if instead, a regular division is made, with uniform units, making the divisions of average value by adding fractional parts from divisions reserved for such a purpose.

Connecticut, though perhaps the most persistent and unfair of them, was not the only claimant of the northwest territory. Virginia asserted her right to a portion of it, and there was, in consequence, granted to that State certain lands in Ohio lying between the Scioto and Miami rivers. It was set apart for the benefit of revolutionary soldiers, hence the name Virginia Military District. No systematic survey of the territory was made, but the earlier settlers picked out the land wherever they could find any that was vacant, and of such shape as suited them best, those coming later being more and more restricted as the process of selection proceeded. Everywhere there is great variation in the area of adjoining tracts, and in hilly districts as along the rivers especially, very irregular boundaries. The tracts are numbered, not, however, in their geographical order, but merely as to their time of location, perhaps the only way possible under the circumstances, but rendering the numbering of little practical use.

THE PUBLIC LANDS.

The plan pursued in laying out the public lands need not be described here further than that it provides for townships six miles square, and sections one mile square. Considering the lack of precedents the plan is deserving of the very highest praise.

There is one drawback which many must have felt if they have never

complained of it, and that is the awkward way of numbering the sections. A more confusing arrangement could not have been easily found, and many persons after long practice are unable to mentally locate them in their relative order. While the ancient Hebrews wrote from right to left, and the Chinese arrange their characters in vertical columns, such is not the most convenient way for people accustomed to other methods, and it would have been vastly simpler and more easily remembered if in numbering sections they had been arranged as ordinary writing is something as shown in the plan in the margin.

In this plan, which might be termed a natural or obvious one, the numbers increase downward by regular addition of six. This matter of numbering is here alluded to not because a change is now recommended, or because the plan shown is a perfect one, but simply to call attention to the general subject of numbering—something not without its importance—at an instance where correct principles are entirely disregarded. The system is, however, uniform throughout a vast territory, and once learned, in connection with the more simple notation of the meridians, parallels, townships and ranges, locations are easily described, and as the sub-division of a section is well provided for definite descriptions of small parcels of say ten acres can be given without reciting the length or direction of a single line. This has greatly simplified the work of the conveyancer, the abstracter, the assessor and tax gatherer, as well as that of the surveyor. For the ordinary operations of the surveyor the sectional system is admirable. The original field notes and maps are a matter of public record, and show very full details of the length of lines, the meandering of streams and a description of the corners and bearing trees. The corners of a section or quarter section once established the sub-divisions are matters of bisection and distribution, and thus working from the whole to parts bearing a numerical ratio to it great accuracy is possible, in particular those due to imperfect standards of measure can be almost entirely eliminated.

1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

In an open or level country all of the corners along a section boundary can generally be put into a single line, thus fixing the position of a line by points beyond it in its own direction, and not depending on cross measurements or rectangular co-ordinates. In wooded or hilly districts the half-mile points can be used instead, and the intermediate points put in the same way without any unreasonable expenditure of time in running long lines.

The improvement that might be made in the general plan of laying out the public lands will not now be discussed. The more noticeable faults are not so much of deficiency of plan as those caused by defective execution of the surveys. Being done on the frontiers of civilization, the work is at best done at a disadvantage, and often with considerable hardship, if not actual peril to those engaged in it. There is little inspection

by competent officials, and still less criticism through the effective process of public opinion. As there is competition the work must be done cheaply, and of necessity rapidly. Patient, thorough work takes time and money—sometimes so much that an accurate survey would cost more than the land was worth.

These contract surveys are, however, often erroneous beyond all excuse, and the marking of corners little more permanent than the surveyor's own footprints; and, worse still, though full sets of field notes were returned, they were made up from imagination, no survey having been made at all. It is generally possible, however, to make resurveys, and thus obviate some of the inconvenience arising from this source.

That there should be great precision is not often possible under the circumstances under which the most of such surveys are made is no doubt true, and the absence of it is not of itself so serious a matter as many are apt to believe. Indeed, the thing of most importance besides the prevention of unnecessary and easily prevented errors, is the conspicuous and permanent marking of corners. This well attended to, minor inaccuracies of measurement and area may be overlooked as a matter of less importance, and which can be attended to and improved upon as increased values justify more accurate surveys.

That the plan of laying out the public lands is perfect would not be claimed. Doubtless something of value could be learned from the experience of Canada and other countries which have had occasion to solve the same problem. In Canada the principle of decimal division is recognized, but a description of the system is omitted from lack of time to fairly present it in these limits.

But the sectional system is so far in advance of any examples previously afforded in any of the older States, it might be termed, in comparison, perfection itself. Nor is it believed on an average that its execution is worse. It is interesting to observe after the lapse of thirty, forty or fifty years, or even longer, since the settlement of particular districts how closely the lines of ownership follow the section lines.

Among the earliest of these sectional surveys are found in Columbiana, Carroll, Stark and other counties in Ohio. Though over eighty years have passed, and several generations have occupied the soil of these important and thriving civil communities, the sectional divisions are by no means supernumerary or obsolete, the most noticeable variations being found in the hilly districts, where the roads are necessarily winding, and in some instances the deep ravines have been used instead.

In the more level districts the variations are exceptional, and in many counties in States further West such variations are almost unknown.

The credit of designing the public land system has been usually awarded to Col. Jared Mansfield, Surveyor General of the United States. The great Jefferson, it is said, also honored the subject with his attention, and doubtless each of these and others did something toward perfecting and shaping the plan adopted, but Col. Charles Whittlesey, an authority of the very highest respect, in his valuable paper on "Ohio Surveys," recently published,* is inclined to award the palm to Thomas Hutchins as the man in whose brain the conception first found lodgment, and who

* Transactions Wes. Res. & N. O. Historical Society, Tract No. 59.

was one of the instruments in having it adopted. The honor is a great one, and his name may be fitly listed on the roll of great benefactors of mankind.

Hutchins was a Captain in the Sixtieth Royal Regiment and engineer to the expedition under Col. Henry Bouquet, in 1764, during which time, in the lonely forests of Ohio, remote from the scenes of civilized life, and from contact with men, or their accumulated experience, as recorded in books, he evolved in his mind the outline of the plan which was afterward adopted with but little change during the time he was geographer to the confederation, an officer similar to the Surveyor General, afterward filled by Mansfield. Hutchins died in Pittsburgh in 1788, and his remains lie unnoticed in the cemetery of the First Presbyterian Church of that city. History has certainly done him scanty justice, and it is worth while to have said a few words to do something toward rescuing his name from oblivion.*

The principle of rectangular division was adopted at a very early period in laying out American cities, the most noticeable exception being in Boston. New York, Philadelphia and Chicago are laid out with great regularity, and even in Boston the newer parts are laid out in the same fashion. In the western cities the public land system affords an excellent basis. In Chicago, for instance, many of the well known thoroughfares, such as Madison, Twelfth, Twenty-second, State and Halsted streets, and Ashland and Western avenues are upon section lines, and many of the other streets are upon regular fractional divisions of them.

The rectangular system has been criticised mainly from its lack of convenience when it is desired to take a diagonal course, and on account of its supposed offense to an artistic or æsthetic taste. To meet this latter objecion some towns, mostly suburban, have been laid out, an instance in point being Riverside, near Chicago, where the lines of the streets are made up of curves something in the manner of the walks and drives in a park or cemetery. However well such an arrangement might suit for residences with ample grounds it might be quite another thing for small lots and business centres. It would at least require greatly increased care in making the surveys, or the restoration of lost lines be very difficult and uncertain.

Some writers urge that the web of the spider offers us a most admirable plan, and the national capital has been laid out with some reference to this theory; another instance being the little city of Watertown, New York. In Cleveland there is also something of the same sort, though fan-shape would perhaps better describe the flare or gradual divergence form parallelism exhibited by Superior, Euclid, Garden and Woodland streets and avenues. If it were a fact that every one must daily or

* Since the above was written there has appeared in a recent number of this JOURNAL, Vol. 2, p. 282, an interesting and valuable article on "The Origin and Authorship of the Present System of Government Land Surveys," by H. C. Moore, of St. Louis. Mr. Moore has looked up at the Marietta, O., University some of the original papers of Gen. Rufus Putnam relating to the Ohio Company's purchase, in which the plan is outlined as early as 1783. To fully settle the question is a matter requiring further research. Very possibly the result of such investigation would be that the honor is to some extent a divided one, inasmuch as the plan may have been developed, modified and changed by different persons.

constantly go to a certain point—say, for instance, to the post-office—no arrangement could be better, and anything else would be so exasperating as to force the opening of new avenues to bring it about.

Such is rarely, however, the case. The business and manufacturing interests of a modern city are often widely scattered, and rarely tend to a common focus so definite as to require any such arrangement. There are east sides and west sides; north ends and south ends; uptown and downtown; water fronts and railroad fronts—each with its own interests and attracting its special following.

The advantages of representing upon paper the ownership of land are so varied and serve so many public ends that in a progressive community it is regarded as something indispensable. One of the first attempts of this kind was when, nearly nine hundred years ago, in the reign of William the Conqueror, the celebrated Doomsday Book was prepared. Officers were appointed to traverse the kingdom and make out a list of the land owners (loyalty to the sovereign being, of course, a condition of ownership) and their possessions, something after the manner of the modern assessor. The book is still extant, and has always been regarded as an authority almost as conclusive as inspiration, the object for which it was prepared being to inform the monarch of the resources of his kingdom and on whom he might call for support.

It is something over one hundred years ago since the British ordnance survey was begun. Its original object was to make a map of the kingdom for the use of the military authorities; but, as it progressed, its scope has been enlarged, until its aim is a complete and thorough representation of the topography of the kingdom. The fullness of its detail may be judged by the scale used, that for the whole country being $\frac{1}{2500}$, and for villages and towns $\frac{1}{500}$. It would seem possible, from such a map, to make a very close approximation of the proper route for a railroad or similar public work.

In this country the preparation and publication of maps, except of the sea coast, the great lakes and some of the uninhabited territories and mineral districts, has been mainly through private enterprise, which has rarely conducted surveys of any consequence; and, where there are no regular divisions, such maps are necessarily incomplete to an extent that something more thorough and extensive is now a well-recognized public need, and, with the constant reiteration of the demand, may be set down as very likely to be early undertaken. But, whether such a general survey is made or not, the existing divisions, especially the regular ones, should be kept up. They are the framework or skeleton to which all ownership clings, and the preservation of their corners and their restoration and marking when lost may well, and ought to, receive the attention of the State and be no longer left to the caprice of individual interest.

Whatever may be accomplished in a general way by geodetic and trigonometric surveys, the importance and necessity of which need not be undervalued, however fully and satisfactorily they may solve various interesting and important scientific questions, as, for instance, the figure of the earth as well as serving many practical ends in map-making and the accurate determination of levels, the representation of contours, and

in so many other ways justify their existence to an extent that will make their cost seem insignificant in comparison to the results attained. It is, I think, a grave mistake too generally prevalent to suppose that the lines laid down by such surveys will ever be generally relied upon to establish the lines of individual ownership. In the nature of the case the lines of a trigonometrical survey are largely artificial ones, made for a particular occasion, and, however carefully selected and good originally, in the lapse of years may become wholly unsuitable by reason, for instance, of the erection of buildings or the growth of trees. The initial points, too, will often occur in fields or at points where no one is specially interested in their preservation or to be informed of their whereabouts, or, if often resorted to, might cause complaint from the farmer who might find it convenient to have them removed. It must be borne in mind also that were such points used, and the angles turned from them, it would still be necessary then as now to actually run, measure and mark the property lines, for that indeed is the object for which nearly all land surveys are made. In actual practice the accurate determinations of and marking of lines of the various trigonometrical surveys has not often been carried down far enough to make them convenient for such use, much of the detail work having been done with the plane table. The restoration of lost boundaries, too, is often a question of evidence, much of which can only be found on the line itself. Such is the rule of law, the final arbiter, to which all must submit when controversy ensues.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ANNUAL REPORT OF THE CHAIRMAN OF THE BOARD OF MANAGERS.

To the Association of Engineering Societies:

The second report of the transactions of the Board of Managers has been delayed far beyond the proper time for it appearance, mainly because the second volume of the JOURNAL OF THE ASSOCIATION was not completed until near the first of March, 1884.

The intention had been from the first to issue a number of the JOURNAL for each calendar month; an undertaking that was accomplished without great difficulty for the first volume. Owing to but little matter being supplied by some of the societies during last year, the issues of the JOURNAL were seriously deranged before the Board realized the necessity of consolidating two numbers into one issue. Even after the necessity of such action became manifest it was only with reluctance that such a step was taken, as it has been deemed important to maintain a monthly publication. The process of consolidation will be continued until the date of issue corresponds to the month printed on the cover.

After this is done it will remain for the board to decide upon the course to be pursued in the future.

Owing to the imperfect manner in which drawings are often prepared, and to the slowness of authors in returning proofs to the Secretary, there will always be considerable delay in the publication of certain papers.

No meeting of the Board has been held since the 22d of June, 1882, all the business having been transacted by correspondence. It is desirable that a meeting should be called at an early date to consider many questions of importance vitally affecting the prosperity of the Association.

That the Association should be so managed as to enlarge its field of action and increase its usefulness beyond the mere publication of papers and society proceedings is a proposition plain to every one. Just how to bring about such a result is not so plain, however.

The articles of association under which we act make provisions for readily securing amendments and additions thereto, so that it is possible to direct the course of the Association in such manner as to lead to results of the greatest consequence to the engineering profession.

A confederation of engineering societies, which would be one in fact and not in name, should be the outgrowth of this Association.

It rests with the societies now belonging to the Association to make it such. It can not be done by individuals acting in the capacity of a board, however capable they may be. The interest of the societies generally must be enlisted, and their constant support secured. If all is not accomplished at once that ought to be, it furnishes no argument for the abandonment of the present work of the Association.

The publication of the JOURNAL is a sufficiently worthy object in itself, and, in our opinion, should not be abandoned on any account. There is nothing in the financial statement to cause discouragement. There is no doubt that under proper auspices the cost of the JOURNAL will become merely nominal.

The only change in the personnel of the Board of Managers since the date of the last report—indeed since the founding of the Association—was caused by the resignation of Mr. S. E. Tinkham for the Boston Society, and the appointment of Mr. Horace L. Eaton in his stead; and

by the resignation of Prof. Chas. A. Smith for the Civil Engineers' Club of St. Louis, and the appointment of Prof. J. B. Johnson as his successor.

Prof. Smith's resignation was caused by failing health, which he was never able to recover. His sickness resulted in death on the 2d of February, 1884.

In the death of Prof. Smith the engineering profession loses a worthy member, whose earnestness in every cause which would promote the interests of the profession was only equaled by his ability, and the courage with which he undertook the work which his hand found to do.

As one of the earliest and most zealous promoters of the Association of Engineering Societies he deserves the gratitude of every well-wisher of the Association. He was always assiduous in its behalf and a most steadfast believer in its ultimately being able to lead to a confederation of engineering societies.

Those who were best acquainted with his labors regard him as a victim of devotion to his work.

At the end of the second volume of the JOURNAL the number of copies taken by the several societies was as follows, viz.:

Boston Society of Civil Engineers	115
Western Society of Engineers	143
Engineers' Club of St. Louis	77
Civil Engineers' Club, of Cleveland	125
Total	460

At the end of the first volume the total was 405 copies, a gain of 55. Since the last report assessments to the amount of $3 per copy have been levied by the Board, in two installments of $1.50 each. The expenditures of the association have been as follows for Vol. II., viz:

Composition, press work, paper, binding, and mailing	$957.65	
Engraving	114 68	
Miscellaneous expenses	10.05	
Postage	42.19	
Salary of Secretary	291.66	
		$1,416.23
Receipts:		
Cash balance	$239.08	
Boston Society of Civil Engineers	334.50	
Western Society of Engineers	424.50	
Engineers' Club of St Louis	217.50	
Civil Engineers' Club of Cleveland	325.50	
Advertising	26.00	
Sales and subscriptions	102.40	
Engraving	1.00	
		1,670.48
Leaving a balance on hand		$254.25
There is due for advertisements		247.00

What portion of this will be collected it is impossible to say.

Since the organization of the Association there has been paid by the several societies, including the entrance fee, the following amounts, viz.:

Boston Society of Civil Engineers	$760.00	
Western Society of Engineers	970.50	
Engineers' Club of St. Louis	490.00	
Civil Engineers' Club of Cleveland	679.50	
		$2,900.00
Less cash balance		254.25
Net cash to end of Vol. II		$2,645.75

The average numbers of copies of the JOURNAL taken by the societies is 418, which makes the average cost to the societies per copy, per volume, $3.16, without allowing for advertisements due, or extra copies of the JOURNAL on hand.

When the extra copies are sold, as they will be sooner or later, the receipts from this source will probably not be very different from the following:

20 full sets Vol I. @ $3	$60.00
Additional copies, Vol. I	20.00
175 full sets Vol. II. @ $2.50	437.50
Possible receipts from advertisements	200.00
	$717.50

If this sum is credited to the Association the cost per copy per volume will be $2.31.

Respectfully submitted on behalf of the Board of Managers.

March 31, 1884.

BENEZETTE WILLIAMS, Chairman.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

THE EFFICIENCY OF COMPRESSED AIR.

By C. M. Woodward, Member of the Engineers' Club of St. Louis.

[Read February 13, 1884.]

[Introductory Remark.—In this paper the author makes no claim to originality; his only aim has been to present the principles in as simple and intelligible a form as possible. He has great faith in diagrams, as full of suggestion when properly drawn. He hopes the illustrations of this paper will prove to be of value.]

1. If v is the volume of a unit weight of a perfect gas which is throughout under a uniform pressure p, and at a uniform absolute temperature T, then the value of the expression $\frac{v\,p}{T}$ is constant. If this constant be called R we have $\frac{v\,p}{T}=R$ (I.). p gives the pressure (in pounds, kilograms or atmospheres as may be desired) upon a unit of surface, and v gives the volume in cubes of the unit of length. The temperature may be given in degrees Fahrenheit or Centigrade; if in the former, T is 459.4 degrees more than shown by a Fahrenheit thermometer; if the degrees are Centigrade, T is 273 degrees more than shown by a Centigrade thermometer.

2. Equation (I.) shows that if the pressure is constant, the volume increases and decreases with the temperature, or, more exactly, that the volume is proportional to the temperature. Hence, if the temperature increases by equal increments, the volume will increase by equal amounts. Now if p is constant, the equal increments of volume show that equal amounts of external work are done by the expanding gas as the temperature increases by regular degrees.

3. If we consider next the amount of heat required to raise our unit weight of gas through one degree of temperature, and then another, and so on, the pressure being all the while constant, we shall see that a certain part of it is used to do the external work, which is the same in each

case, because the increments of volume are equal, and that the remainder is used to increase the temperature of the gas itself, that is, in making the gas hotter. Now it has been found by experiment:

First. That for all ordinarily attainable temperatures air is a perfect gas.

Secondly. That that portion of the heat required to merely heat the gas one degree (not including that spent in doing the external work) is constant.

Thirdly. That this last constant amount of heat is precisely the same as that required to heat from any one degree to the next a unit weight of air which is so confined that it cannot expand, and consequently can do no external work.

4. This last amount of heat, required to heat a unit weight of air through one degree at constant volume is therefore *constant*, whatever be the temperature and pressure; this amount of heat will be designated by C_v, and will be read, "specific heat at constant volume." If now, in addition to being heated, the air is allowed to expand, the pressure being constant, more heat is required on account of the external work to be done; but as this amount of work is also constant, the sum is constant, and the total is denoted by C_p, and is read "the specific heat at constant pressure." It is evident that C_p is greater than C_v by the heat required to do the external work involved in the expansion while the air is heated through one degree.

5. It is now easy to show that this difference between C_p and C is just the quantity R given in equation (I.). For let us suppose that, p being all the while constant, the temperature is reduced to absolute zero, where T becomes zero. In this ideal state of things all heat, and hence all energy, has gone out of the air; it is therefore without the power of physical manifestation, shown by the logical necessity of writing the volume equal to zero also.

Next let us suppose that the air receives heat and expands at constant pressure till the volume is v and the temperature T. It is evident that the whole work done by the air as it expands from no volume till its volume is v, is $v\,p$,* and since this is the work done while the temperature is increasing from zero to T we find the work done during the rais-

* It may be well to show that if a pound of air expand from v_1 to v_2 against a constant pressure p, the work done by the air is $(v_2 - v_1)\,p$. Suppose the air to be in a cylinder with unyielding sides and one fixed end, and that as the air is heated and expands it drives along a piston. Let A be the area of the piston. Then the length of the cylinder of air before expansion must be $\frac{v_1}{A}$ and after expansion $\frac{v_2}{A}$. Hence, the piston has been forced along a distance $\frac{v_2 - v_1}{A}$. The pressure on the piston is $p\,A$, so that the work done during expansion is $\frac{v^2 - v_1}{A} \times p\,A = (v^2 - v_1)\,p$, which was to be shown. If the pressure during an expansion is not constant the work must be computed for small parts of the expansion separately and the results added. In other words, make the difference between v_2 and v_1 very small (denoted by $d\,v$) so that an element of work will be represented by $p\,d\,v$, and then sum the series (or integrate the differential). Hence, the general expression for work against a varying pressure is $\int p\,d\,v$. If, as in Section 5, the pressure is constant and v_1 is zero, we have $W = \int_0^v p\,d\,v = p\int_0^v d\,v = p\,v$ where W stands for the work done.

ing of the temperature one degree, by dividing the whole work by T, the number of degrees. Hence it is $\frac{v\,p}{T}$; but this is R; so that the difference between the two specific heats is R, and we have the equation

$$C_p - C_v = R.^* \qquad \text{(II.)}$$

6. If our units are the foot, the pound and the degree Fahrenheit, the numerical value of R is thus found: Let p be the atmospheric pressure, or 2,116.3 pounds per square foot; T the absolute temperature of melting ice under normal pressure, or 491.4 degrees; then, by measure, v for air is known to be 12.387. Hence the value of R, which is always equal to the quotient of the three simultaneous values:

$$\frac{v\,p}{T} \text{ is } \frac{12.387 \times 2116.3}{491.4} = 53.35 \text{ foot-pounds.}$$

Had the units been the kilogram, the meter and the degree Centigrade, the value of R would have been numerically 29.27.

The values of C_p and C_v are 183.35 and 130.00 foot-pounds respectively.

The ratio of C_p to C_v is approximately 1.41.

7. Let us now suppose that one pound of air receives a small amount of heat, which we will denote by dQ; and that in consequence the air becomes slightly warmer, indicated by dT; and at the same time that it increases a little in volume, denoted by dv; in other words, that a part of the heat is used to increase temperature, and a part to increase the volume. To merely increase the temperature one degree would require C_v units of heat; to increase the temperature dT requires $C_v\,dT$ units; to do the external work requires pdv; the general equation for a perfect gas is therefore

$$dQ = C_v\,dT + pdv \qquad \text{(III.)}$$

It should be understood that no waste heat is included in dQ of this formula. Either we must suppose that the heat passing into or through the material of the cylinder is left out of account, or we must assume that the cylinder is non-conducting, so that there is no waste heat. Whichever way we regard it, the assumption is not to be forgotten.

8. Equations (I.), (II.) and (III.) lead to all the formulæ we shall use. If (III.) be integrated from the condition v_1, T_1, p_1 to v_2, T_2, p_2, we shall have

$$Q = C_v(T_2 - T_1) + \int_{v_1}^{v_2} pdv;$$

we cannot integrate $\int pdv$ unless we know the relation of p to v for every condition intermediate between v_1, p_1 and v_2, p_2.

If there is no change of temperature, then $T_2 - T_1 = 0$, and since $p = \frac{T\,R}{v}$ from (I.), we have

$$Q = T\,R\int_{v_1}^{v_2}\frac{dv}{v} = T\,R\,(\log. v_2 - \log. v_1) = T\,R\log.\frac{v_2}{v_1}. \qquad \text{(IV.)}$$

9. In the ordinary operations of compressing or using compressed air

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*In this equation we have the difference between two amounts of heat placed equal to a certain number of foot-pounds or to a number of kilogrammeters. This shows that we are measuring heat by the work it can do, or in *dynamic* units. Heat is often measured in *thermal* units, as, for example, by the amount of water it can heat or in the weight of ice it can melt. These units are convertible, but the simplest unit for our use is the dynamic.

there is little or no direct transfer of heat; we shall therefore derive the equations for such operations by putting $dQ = 0$, and by integrating equation (III.) by means of equation (I.)

To find the relation between p and T when there is no transfer of heat, we let $dQ = 0$ in (III.): whence

$$C_v\, dT + pdv = 0. \qquad \text{(V.)}$$

Differentiating (I.) we have $pdv + vdp = RdT$,

$$\text{or } pdv = RdT - vdp = RdT - \frac{RT}{p}dp$$

Substituting in (V.) we have

$$(C_v + R)\, dT = \frac{RT}{p}\, dp,$$

$$\text{or } \frac{C_v + R}{R} \times \frac{dT}{T} = \frac{dp}{p},$$

$$\text{or by (II.) } \frac{C_p}{C_p - C_v} \times \frac{dT}{T} = \frac{dp}{p} = \frac{k}{k-1} \times \frac{dT}{T}$$

in which we denote by k the ratio of the two specific heats, or $\frac{C_p}{C_v} = k$.

Integrating our last equation from p_1, T_1 to p_2, T_2, we have

$$\frac{k}{k-1} \log. \frac{T_2}{T_1} = \log. \frac{p_2}{p_1}:$$

$$\text{whence } \log. \left(\frac{T_2}{T_1}\right)^k = \log. \left(\frac{p_2}{p_1}\right)^{k-1}$$

$$\text{or } \frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} \qquad \text{(VI.)}$$

This equation gives the ratio between the absolute temperatures when the pressures are known, and the value of T_2 when T_1, p_1, p_2 are known.

10. To find the relation between p and v when $dQ = 0$, we have, eliminating dT from (V.) by substituting the value of dT obtained by differentiating (I.),

$$C_v \frac{pdv + vdp}{R} + pdv = 0.$$

$$\text{Whence } (C_v + R) \times pdv = -\, C_v\, vdp$$

$$\text{or } \frac{C_p}{C_v} \times \frac{dv}{v} = k\frac{dv}{v} = -\frac{dp}{p}$$

Integrating from v_1, p_1 to v_2, p_2 we get

$$k \log. \frac{v_2}{v_1} = -\log. \frac{p_2}{p_1} = \log. \frac{p_1}{p_2};$$

$$\text{whence } \left(\frac{v_2}{v_1}\right)^k = \frac{p_1}{p_2} \text{ or } \frac{v_2}{v_1} = \left(\frac{p_1}{p_2}\right)^{\frac{1}{k}} \qquad \text{(VII.)}$$

which gives the ratio between volumes when the pressures are given.

11. Combining (VI.) and (VII.) we readily get

$$\left(\frac{v_2}{v_1}\right)^k = \left(\frac{T_1}{T_2}\right)^{\frac{k}{k-1}}: \text{ or } \frac{v_2}{v_1} = \left(\frac{T_1}{T_2}\right)^{\frac{1}{k-1}};$$

$$\text{or } \frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1} \qquad \text{(VIII.)}$$

This could also be found from (V.) by eliminating p and integrating.

12. In section 5 we spoke of the work done by the expanding air as a positive quantity. To be consistent we should then prefix the negative sign to the work done (by an engine, for instance) in compressing the air. It will be more convenient, however, to denote the work done by whatever motor as positive ; so that for $\int pdv$ in (V.) we shall write $-W$, and (V.) becomes

$$W = \int C_v \, dT = C_v \, (T_2 - T_1) \qquad \text{(IX.)}$$

This equation gives the work done in compressing one pound of air from the condition v_1, p_1, T_1 to the condition v_2, p_2, T_2.

13. Now let us find the work done by the pumps while compressing a pound of air from p_1 to p_2, and then forcing it out of the cylinder into a reservoir where the pressure is constantly p_2. As has just been seen, the work of compression is $C_v \, (T_2 - T_1)$, the volume of the air is now v_2, so that the work of forcing the air out of the cylinder is $v_2 \, p_2$; hence the total work is

$$C_v \, (T_2 - T_1) + v_2 \, p_2.$$

But this is not wholly due to the engine ; the pressure on the *outside* of the piston is uniformly p_1 throughout the whole stroke, so that the work $v_1 \, p_1$ is actually done by the atmosphere. Subtracting this from the total work and we have as the work of the compressing pump

$$W_c = C_v \, (T_2 - T_1) + v_2 \, p_2 - v_1 \, p_1.$$

But when the volume was v_2 and the pressure p_2, the temperature was T_2, so that by (I.) $v_2 \, p_2 = RT_2$. Similarly $v_1 \, p_1 = RT_1$, so that we have

$$W_c = C_v (T_2 - T_1) + R \, (T_2 - T_1) = (C_v + R) \, (T_2 - T_1) = C_p \, (T_2 - T_1). \qquad \text{(X.)}$$

This shows that the work of the compressor is directly proportional to the *change of temperature of the air while in the compressor.*

14. *Graphics.*—Our results may be illustrated very fully by diagrams. Equation (I.), being an equation between three variables, may be regarded as the equation of a surface referred to rectangular co-ordinates, the axes being p, v and T. It is readily seen that the surface is a hyperbolic-paraboloid. If T is constant, we get a curve of the surface which is called an "isothermal" curve ; its projection upon the plane of volume and pressure axes is represented by the equation $pv = RT =$ a constant. This is the equation of an equilateral hyperbola. Every point in the surface represents a separate condition of the pound of air, as regards v, p and T. Any change in the condition of the air, whether arising from expansion, compression, heating or cooling, will be accompanied by a change in the position of its representative point on the surface ; so that a connected series of changes of condition is always represented by a line, straight or curved, on the surface. An isothermal curve represents a series of conditions which our pound of air can be made to pass through only by the direct transfer of heat to or from it as it expands or is compressed. If, however, it expands against pressure, or is compressed, without any transfer of heat, the change is said to be *isentropic*, and the curve of the surface representing the successive conditions is called an *isentropic*

curve. [Professor Rankine calls it an *adiabatic* curve.] Equation (VII.) gives the projection of an isentropic curve on the plane of volume and pressure, if in the place of v_2 and p_2 we write the general values v and p; thus :

$$v = v_1 \left(\frac{p_1}{p}\right)^{\frac{1}{k}} \quad \text{or } p = \frac{p_1 v_1{}^k}{v^k} \qquad \text{(XI.)}$$

In Fig. 1 let $O\ V$ be the axis of volume, and $O\ P$ the axis of pressure. $A\ B\ C$ is a portion of an isentropic curve, and $R\ B\ T_2$, an isothermal.* Let A denote the condition of the pound of air when v, p and T are v_1, p_1, T_1. In like manner let B denote the condition v_2, p_2, T_2. $O\ M_1. = v_1$, $O\ M_2 = v_2$, $A\ M_1 = p_1$, $B\ M_2 = p_2$. Then the total work during the compression $= C_v\ (T_2 - T_1) =$ the area $A\ M_1\ M_2\ B$. The work of forcing the air out of the cylinder into the reservoir $= p_2\ v_1 =$ the area $B\ M_2\ O\ N_2$. The work done by the external air during the whole stroke is $v_1 . p_1$, — the area $A\ M_1\ O\ N_1$. Hence

$$W_c = C_p\ (T_2 - T_1) = \text{the area } A\ N_1\ N_2\ B.$$

15. The temperature with which the air leaves the compressor is not maintained. In the reservoir tank and in the pipe leading to the air-engine the temperature generally falls nearly if not quite to the original temperature T_1, while the pressure is not measurably diminished. This loss of heat involves a loss of volume, so that the condition of our pound of air as it enters the cylinder of an air-engine is v_3, p_2, T_3. These are simultaneous values and hence satisfy equation (I.), as does every other set of simultaneous values. T_3 may not differ measurably from T_1, but in general it will differ several degrees.

In the use of the air in the engine it will be assumed that it enters the cylinder under full pressure, and then expands without direct transfer of heat till the pressure falls to p_1. The work done will be by the air, so that no change of sign is needed in this case.

16. On entering the cylinder under full pressure the work done by our pound is $v_3\ p_2$. It then expands till the pressure falls to p_1 and the temperature to T_4. The work done by the air in expanding is $C_v\ (T_3 - T_4)$ in

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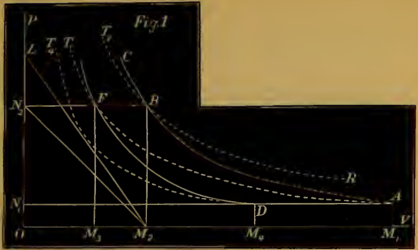
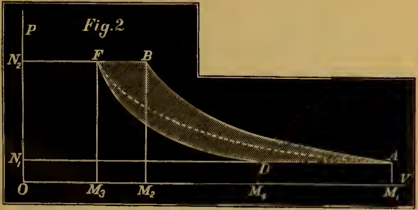
[Remark upon the Diagram.—The curves in the figures are drawn to scale from their equations, so that the proportions are very nearly correct. The range of pressures is from *one* to *five* atmospheres. The graphical results, therefore, appeal to the eye with their proper force.—C. M. W.]

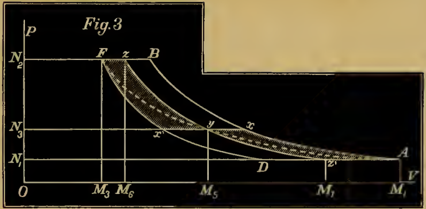
* Considering the axis $O\ P$ as vertical, we may always say that when an isentropic and an isothermal curve intersect, the former is always the *steeper* curve. This may be shown from the two values of $\frac{dp}{dv}$ for the point of intersection. From the equation of the isothermal, which may be written $p = \frac{v_1\ p_1}{v}$, we get $-\frac{dp}{dv} = \frac{v_1\ p_1}{v} = \frac{p}{p_1} \times \frac{p_1}{v} = \frac{p}{v}$. From equation (XI.) which represents the isentropic curve, $-\frac{dp}{dv} = \frac{kp_1\ v_1{}^k}{v^{k+1}} = k \times \frac{p_1\ p}{v\ p_1} = k\frac{p}{v}$ which is numerically greater than $\frac{p}{v}$ since k is greater than one. Hence the isentropic has the greater *slope*, or is the steeper. The tangent to the isothermal $R\ B\ T_2$ at B is parallel to $M_2\ N_2$, while the tangent to the isentropic $A\ B\ C$ at the same point is parallel to $L\ M_2$, $O\ L$ being equal to $k \times O\ N_2$. The numerical value of k is 1.41.



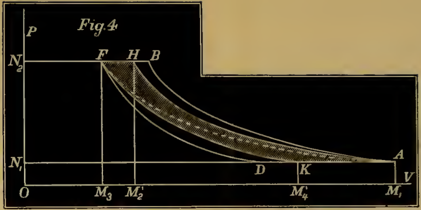
ISENTROPIC AND ISOTHERMAL LINES.



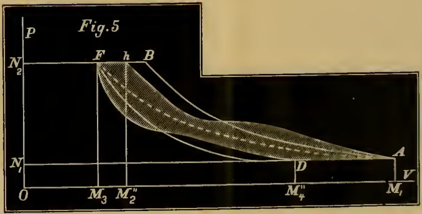
LOSS OF ENERGY WITH NON-CONDUCTING CYLINDERS.



SAVING OF ENERGY BY A COMPOUND SYSTEM.



SAVING EFFECTED BY COOLING AND HEATING JACKETS.



EFFECT OF METALLIC CYLINDERS IN NON-CONDUCTING JACKETS.

accordance with (IX.). But a part of this work is done upon the external air which resists the motion of the piston by the constant pressure p_1. To get the available work we must subtract from the work done the product $v_4\, p$, v_4 being the final volume of the air which leaves the cylinder at a temperature T_4. The work of the air-engine is then

$$W_e = C_v(T_3 - T_4) + v_3\, p_2 - v_4\, p_1$$

But $v_3\, p_2 = R\, T_3$, and $v_4\, p_1 = R\, T_4$, so that

$$W_e = C_v(T_3 - T_4) + R\,(T_3 - T_4) = C_p(T_3 - T_4) \qquad \text{(XII.)}$$

This result might have been inferred from equation (X.).

17. We are now able to compare the work done by the air-engine per pound of air with the work done by the compressor. Dividing (XII.) by (X.), we have for the efficiency E.

$$E = \frac{W_e}{W_c} = \frac{T_3 - T_4}{T_2 - T_1} = \frac{T_3}{T_2} \times \frac{1 - \frac{T_4}{T_3}}{1 - \frac{T_1}{T_2}} = \frac{T_3}{T_2} \qquad \text{(XIII.)}$$

for $\frac{T_4}{T_3} = \frac{T_1}{T_2}$ since each is equal to $\left(\frac{p_1}{p_2}\right)^{\frac{k-1}{k}}$ by (VI.).

18. If $T_3 = T_1$, $\qquad E = \frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{k-1}{k}} \qquad$ (XIV.)

Since by (VI.) $T_2 = T_1 \left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}}$, we find that E of (XIII.) becomes

$$E = \frac{T_3}{T_1} \times \left(\frac{p_1}{p_2}\right)^{\frac{k-1}{k}} \qquad \text{(XV.)}$$

which shows that for a given range of pressure the *efficiency will be increased by increasing T_3 or by decreasing T_1.*

19. *Graphical Representation of Work Lost.*—In Fig. 2, as in Fig. 1, let A represent the condition of the air at p_1, v_1, T_1; and B at p_2, v_2, T_2. The area $A\, N_1\, N_2\, B$ was shown in § 14 to represent the work of the compressor. While in the reservoir, or in the engine supply pipes, the pressure being constantly p_2, the temperature falls to T_3, and the volume is reduced to v_3; this condition is represented by the position of F. In the figure, T_3 is assumed to be the same as T_1. In the condition F the air enters the cylinder of the engine. The work it does at full pressure is represented by the area $F\, M_3\, O\, N_2 = v_3\, p_2$. The air then expands till the pressure is reduced to p_1, the volume is v , the temperature is T_4, and the condition of the exhaust is represented by the point D, and the work done during expansion is represented by the area $F\, D\, M_4\, M_3$. After subtracting the work $v_4\, p_1$ done in overcoming the atmospheric pressure, the *useful* work remaining is represented by the area $F\, D\, N_1\, N_2$; and as the work by the compressor was $A\, B\, N_2\, N_1$, the *work lost* through the cooling of the air between the compressor and the engine is fully represented by the shaded area $A\, B\, F\, D$. The object of all modifications of the processes we have followed should be to *diminish* this loss, or graphically, to reduce the area $A\, B\, F\, D$.

20. This loss may be diminished in several ways:

(a.) Reduce the temperature T_1 of the air entering the compressor as

much as possible. This will bring the point A nearer D (and consequently B nearer F), thus reducing the area on the outside. This reduction can be made by drawing the air through cold vaults, caverns, or cellars, where the volume of a pound of air is less than that of air at the average temperature.

(b.) Raise the temper T_3 of the air entering the air-engine as much as possible. This will shorten the line $B\ F$, and also the line $D\ A$, and so save much that was lost. If the compressed air supply can be heated by what would otherwise be waste heat, such as solar heat, chimney gases, or hot refuse-water, it should be done.

(c.) Divide the work of compression into two parts, allowing the temperature to fall to T_1, after the work of compression is half done in one cylinder, and then completing the work in a second cylinder. The saving thus effected is shown in Fig. 3 by the quadrilateral $x\ y\ z\ B$, which is saved on the work of compression. This will involve a second tank, and, generally, arrangements for rapid cooling of the air, and the saving will be a maximum when the intermediate pressure is a mean proportional between the extreme pressures. Thus, if p_2 the highest pressure is 9 p_1, the intermediate pressure should be 3 p_1 ; and it will be as much work to compress the pound of air from *one* atmosphere to *three* as from *three* to *nine*, the temperatures at the two compressors being the same. The volume of the second cylinder should be to the volume of the first in the ratio of OM_5 to OM_1, or of the 2 k-th roots of the extreme pressures. Thus, if the air is to be compressed from one to nine atmospheres by a compound compressor, the small cylinder should have 0.46 of the volume of the larger.

(d.) In a similar manner the air could be used in a compound engine, the air being heated up to T_3 after escaping from the first cylinder. This would increase the work of the engine and diminish the area of loss in the diagram by a quadrilateral $x'yz'D$. The intermediate pressure should correspond to the intermediate pressure during the compression.

(e.) Withdraw the heat from the air as rapidly as possible during compression, by a cooling jacket or otherwise. The curve which represents the condition of the air under these circumstances is intermediate between an isentropic and an isothermal curve, as is shown in Fig. 4 by the curve $A\ H$. This effects a great saving.

(f.) Supply heat to the expanding air in the engine cylinder by a hot jacket. This result will be shown by the modified curve FK in Fig. 4, which exhibits a clear gain.

Two or more of these methods of saving may be adopted* at the same time.

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* It may be well to say that if the working cylinder, either of the pump or of the engine, is inclosed in a non-conducting jacket, the heating and cooling effects of a metallic cylinder neutralize each other and the effect is that of an isentropic compression or expansion. This is illustrated by the irregular curve $A\ h$ in Fig. 5. The first effect of the heated cylinder upon the air would be to increase the pressure by heating it. Later in the stroke the temperature of the air rises above that of the metal, and the effect of the cylinder then is to keep down the temperature and also the pressure. With a non-conducting jacket, no heat passes *through* the cylinder, and hence the effect is that of a non-conducting cylinder.

21. *Numerical Results.*—When $T_3 = T_1$ and none of the methods given above for diminishing the loss are used. Equation (XIV.) gives

$$E = \left(\frac{p_1}{p_2}\right)^{\frac{k-1}{k}} \text{ and from}$$

$$\text{equation (VI.) we have } T_2 = T_1\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} = \frac{T_1}{E},$$

$$\text{and } T_4 = T_1\left(\frac{p_1}{p_2}\right)^{\frac{k-1}{k}} = T_1 E;$$

$$\text{and } \frac{k-1}{k} = \frac{0.41}{1.41} = 0.29.$$

If the temperature of the air at first is 60 degrees Fahr.,

$$T_1 = 60 + 459 = 519.$$

The following table gives the efficiency and the temperatures, both of the high pressure air and at the exhaust, for various ranges of pressure :

$\frac{p_1}{p_2}$	$\frac{p_2}{p_1}$	E	T_2	T_4	t_2 deg. Fahr.	t_4 deg. Fahr.
					Degrees.	Degrees.
1-2	2	0.815	634	423	175	— 36
1-3	3	0.727	714	377	255	— 82
1-4	4	0.669	776	347	317	— 112
1-5	5	0.627	828	325	369	— 134
1-6	6	0.595	873	309	414	— 150
1-7	7	0.569	912	295	453	— 164
1-8	8	0.547	949	284	490	— 175
1-9	9	0.529	981	275	522	— 184

22. *Numerical Results for Compound Cylinders.*—Since the results of the table just given do not depend on the absolute values of p_1 and p_2, but only on their ratio, it is evident that the efficiency of a compressor and engine working between three atmospheres and nine atmospheres is the same as between one and three atmospheres. It will therefore be seen on a moment's reflection that the efficiency of a compound compressor and compound engine as described in section 20 (c) and (d), working between the extreme pressures, one and nine atmospheres will be the same as for a single compressor and engine between one and three atmospheres ; and that, in general, the efficiency of a compound system (using the proper intermediate pressure and always bringing the pumped or the exhaust air back to T_1) working between two given extreme pressures, is equal to the *square-root* of the efficiency with a single system. Thus :

Ratio of extreme pressures.	2	3	4	5	6	7	8	9
Efficiency of single system............	.815	.727	.669	.627	.595	.569	.547	.529
Efficiency of compound system.......	.90	.85	.82	.79	.77	.76	.74	.73

An examination of the table will also show that the efficiency in column headed 6 is the product of the efficiencies in columns 2 and 3 ; so the efficiency under 8 is the product of the efficiencies under 2 and 4.

ENGINEERING PHOTOGRAPHY.

By D. C. Humphreys, Member of the Engineers' Club of St. Louis.

[Read March 26, 1884.]

In discussing photography this evening, I wish what I have to say to be taken rather as a progress report than as the dictum of an expert, which I certainly do not claim to be, my own knowledge of the subject having been gained chiefly during the last six months in the leisure moments I have had at my disposal, while actively engaged in my regular work. Having so recently passed through the primary department, I suppose I can give good advice to a beginner.

The object which I have in view this evening is to give the principles on which the art depends with some of the chief uses to which it can be applied, which, I hope, will be instructive or interesting to all, and at the same time to give such practical suggestions and formulæ as will be of value to any one who desires to learn to take photographs.

My own knowledge on the subject has been gotten from books, experiments and talks with other amateurs, having learned but little from the regular profession, who, to a greater or less extent, regard it as a secret trade where all information should be paid for. A beginner would probably save time and money by taking a few lessons in a good photographic establishment. That you may understand the change brought about by the introduction of the gelatino-bromide dry plates, which have only been on the market for a few years, some statement of the principles on which photography depends is necessary.

No engineer who has been successively tanned and bleached by field and office work need be told of the power of the sun to greatly modify the color of many substances. The salts of silver are those mostly used, being the only ones known to be capable of use in the camera, while the compounds of iron and chromium are extensively used in sun printing. Silver chloride, iodide and bromide are the salts used, the action of light being nearly the same on each. If light is allowed to fall on the chloride under favorable conditions it is reduced to the subchloride. As is well known, it is the short vibrations of light which so synchronize with the vibrations of the molecules as to throw off one atom of chlorine while the longer vibrations have no effect. The opposite of this occurs when light falls on the eye, so a photographer, by using blue glass and blue curtains, can admit most of the chemical rays into his studio while excluding much of the heat and blinding light, thus enabling his subject to keep cool and to have his eyes wide open. The chemical change is very slight in the silver salt, so that very little energy is necessary, the result depending solely on the vibrations being of the right length, just as the trotting dog may have thrown down a bridge which allowed a four-horse wagon to safely pass over it. Capt. Abney states that chloride of silver may be heated to that point at which it will itself give off chemical rays without being decomposed. The action of light on silver chloride is as follows:

$$2\,AgCl = Ag_2Cl + Cl,$$

this change takes place much more readily if some substance is present to absorb the chlorine, in the presence of moisture we have

$$4AgCl + H_2O = 2Ag_2Cl + HCl + HClO.$$

If silver iodide be used in the presence of free silver nitrate, as in the wet plate process, we have

$$12AgI + 6AgNO_3 + 3H_2O = 6Ag_2I + O + 6AgI + 6HNO_3,$$

the nitrate being capable of absorbing the freed iodine is called a sensitizer. If silver bromide had been used in the above reaction, on account of its greater sensitiveness to light, the following reaction takes place after exposure,

$$4Ag_2Br + 6HNO_3 = 4AgBr + 4AgNO_3 + N_2O_2 + 3H_2O,$$

which, with the aid of the nitrous acid set free, soon destroys the latent image. This accounts for the disappearance of the latent image in the so called tannin dry plates when they are kept after exposure before developing.

With the gelatino-bromide plate the case is quite different, the gelatine acts as a sensitizer, absorbing the liberated bromide without setting free any injurious acid, so that such a plate will keep as well after as before exposure, which seems to be indefinitely if properly made and not allowed to get too hot.

Some manufacturers claim that the plates, like whiskey, improve with age. They probably become more sensitive on account of an increase in the size of the grains of bromide. This property of the gelatino-bromide plates, taken in connection with the fact that they are the most sensitive compound known, make them so superior to all others for engineering purposes that I do not consider it worth while to mention any others, referring you to books on the subject.

Cramer & Norden, of St. Louis, were among the first to manufacture dry plates for the market, in this country, and the Cramer plate is still considered the standard. It is as trustworthy as any, perhaps, but not so sensitive as others I have used. I have not taken a single good instantaneous picture with a Cramer plate. Cramer & Norden dissolved partnership, and the latter is also manufacturing dry plates bearing his name, which one of my friends tells me are the quickest and best in the market. I have used them and the Seed plates, also made in St. Louis, enough to say that both are excellent, but not enough to say which is the better. The best plates I have ever had were from the Crystal Dry Plate Co. of Indianapolis. They were branded instantaneous, and with them I made nearly all my instantaneous views. Other plates which I have got since were not so good. One of my friends gets best instantaneous results with Eastman's Special, which are so sensitive that I have great difficulty in keeping them from fogging. I don't think it makes much difference which of the above brands a beginner starts with, excepting Cramer, for instantaneous work, and Eastman's Special for ordinary work, either of which would probably not give satisfactory results.

THE LENS.

The lens is the most important thing in the outfit, and while the character of this paper does not admit of a full discussion a few remarks may not be out of place.

Makers should, and usually do state in describing a lens the size of

the objective, the equivalent focal length and the size of the plate covered. Lenses are usually compounded to overcome spherical aberration and other obstacles to making a correct picture, and the equivalent focal length is the distance from the optical centre of a compound lens to the ground glass, when the rays striking the objective are parallel. The following equation gives the relation between the conjugate foci of a lens :

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}.$$

Where v is the distance from the optical centre to the image, u the distance to the object, and f the equivalent focal length, it is evident that if u is infinite $v=f$. If the image is to be $\frac{1}{n}$ the size of the object we have :

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{nv} \text{ or } v=\frac{f(n+1)}{n}.$$

The quickness of a lens depends on the size of the objective and the shortness of the equivalent focal length. If r is the radius of the lense and f the focal length, then the time of exposure is given by the equation :

$$t=C\frac{r^2}{f}$$

where C is independent of the lens, depending on the value of the light and the quickness of the plates. By means of this equation the quickness of the different lenses can be readily compared.

The standard lenses are those made by Morrison, Voigtlander, Darlot or Dallmeyer, each of whom makes excellent lenses. The Morrison is an American lens, while the others are not. In 1840 Voigtlander & Son made the first successful portrait lens ever constructed; they have ever since acknowledged no superior, and their euryscope seems to be the favorite lens in America to-day.

For an engineer, especially if he be economically inclined, I recommend, to cover a 5 × 8 plate, Darlot's Rapid Hemispherical No. 1, $15. When used without a diaphragm, or "stop," it does not quite cover the plate uniformly, but with one of the smaller stops does so perfectly. It is a quick lens and embraces an angle of about 65 degrees.

Morrison's Wide Angle View Lens, No. 4, $25, is an excellent lens, especially for work in confined situations, as in photographing street scenes, machinery, etc.

I have an euryscope No. 2, $52, which works well and will cover an 8 × 10 plate if need be. It is not so well worth $52 as my Darlot is worth $15.

Morrison's New Rapid Copying Lens, $40, covering a 5 × 8 plate, is probably as good as any.

THE CAMERA BOX.

The camera box which I have is made by Anthony, and is called "The Novel." I selected it after looking at all I could see in the St. Louis supply stores, and, taking its cheapness into consideration, is probably as well suited to an engineer as any. The important points are that the plate can be used with its longest dimension either vertical or hor-

izontal, that it can be turned about a horizontal axle so as to make the plane of the picture vertical when the camera is pointed up or down, and that the lens should be capable of being moved vertically.

The tripod should be light and portable, folding up so that it can be easily carried.

DRY PLATE HOLDERS.

Of these there are a great variety, but by far the most convenient for an engineer are the paper holders which add very little either in bulk or weight, making them suitable for field work. They are patented, not very well made, and sold high, because one cannot get along well without them.

TIME OF EXPOSURE.

The question of how long to make the exposure is the most difficult one connected with photography, since it depends on so many things, such as the lens, the diaphragm, the quantity and quality of the light and the color of the object. The time varies from the instantaneous, when the object is white and in bright sun light, to hours in enlarging or in photographing microscopic objects.

To give a beginner some idea if he wishes to photograph a landscape with a Darlot lens, medium size stop and in the bright sunlight, 2 seconds will suffice, while I have never succeeded in taking a portrait in an ordinary room with less than 30 seconds exposure when no stop is used. A good way is to expose different parts of the same plate unequally, then notice which exposure gives the best result. The only way to learn is by experiment, and after spoiling many plates the learner will know by intuition how long to keep the cap off. A professional hardly ever looks at his watch, though a beginner should not only observe the time, but should record it.

DEVELOPMENT.

In most processes, and especially in the gelatino-bromide, the latent image is practically invisible, necessitating the use of a developer, whose use depends on the fact that after one atom of silver is precipitated it attracts other atoms as they are thrown down.

The developer first attacks the sub-bromide, shaking off one atom of silver which aids in the precipitation of others, the bromine being absorbed by the developer. The reduction of the silver bromide which has not been effected by light probably takes place according to the formula :

$$Ag + AgBr = Ag_2Br.$$

The so-called iron developer is, all things considered, undoubtedly the best for an engineer, on account of its cleanliness, convenience, and the control it gives in developing plates improperly exposed. The following is the one I use with much satisfaction :

Solution No. 1.	Neutral oxalate of potash	5 ounces.
	Bromide of ammonia	30 grains.
	Water	20 ounces.
Solution No. 2.	Photosulphate of iron	5 ounces.
	Tartaric acid	20 grains.
	Water	20 ounces.

To four parts of No. 1 add one part of No. 2 ; place the plate in the tray and dash the developer over it, wetting the whole plate as nearly simultaneous as possible. For a 5 × 8 plate use 2 ounces of No. 1 and 4

drachms of No. 2. To develop an instantaneously exposed plate increase the amount of iron to about 5 drachms, add a few drops of bromide of ammonia from a solution of ten grains to the ounce ; dash the developer over the plate, and as soon as it is wet pour it off ; add three drops hyposulphite of soda, then pour it back into the tray, after which the picture will come out very rapidly.

The Cramer developer is by many photographers considered the best, and for economy and the excellence of the negatives produced by its use is certainly a very good one. It stains the fingers, and small bubbles form readily in it, like soapsuds, which are liable to stick to the plate and cause spots. It is not so good for developing instantaneous work.

The following is the formula for preparing it :

Stock Solution.

Sulphite of soda (crystals)	3 ounces troy weight.
*Bromide of ammonium	¾ or 1 ounce " "
Bromide of potassium	1 ounce " "
Pyrogallic acid	2 ounces " "
Dissolve thoroughly in pure rain, distilled or ice water	32 fluid ounces.
Add sulphuric acid, c. p.	120 minims.
Concentrated liquid ammonia, 26° B. (sp. gr. 0.900)	3 fluid ounces.
And water to make up bulk to 40 ounces.	

* If you prefer intense negatives, use 1 ounce bromide of ammonium, but if you prefer soft negatives, ¾ ounce will be best and will allow shorter exposures.

Dilute sufficient for one day's use in the proportion of 1 part stock solution to 11 parts of water. Use a rubber stopper for the stock solution.

FIXING.

After development the negative is washed and put into the fixing bath which is prepared by dissolving one pound of hyposulphite of soda in a half gallon of water. In warm weather an addition of alum is beneficial. The hyposulphite dissolves the unaffected salts of silver. After fixing wash thoroughly.

Gelatine negatives frequently need intensifying, for which purpose I use England's mercuric intensifier.

Mercuric chloride	1 part.
Ammonic chloride	1 "
Water	20 to 24 parts.

Pour the intensifier over the negative and rock the tray until the picture turns white; then wash thoroughly, after which put it in water containing a small quantity of ammonia, which turns it black.

As a rule for engineering purposes the negatives do not need either retouching or varnishing.

SILVER PRINTING.

The art of silver printing is an old one and to-day does not differ greatly from that described by Fox Talbot in a paper read before the Royal Society in January, 1839.

Not much, therefore, need be said on the subject, the most important thing being the list of necessary articles given at the end of this paper. A few remarks concerning my methods may not be out of place.

The silver bath which I use is the following :

	Ounces.
Silver nitrate	2
Water	16

Considerable latitude is allowable in the proportions, but the quantity of silver should never fall below 45 grains to the ounce. Float the albu-

menized paper on the bath for two minutes. In putting the paper on the bath, let the middle of the albumenized side touch first, then press down the edges, breathing on the back of the paper if the edges start to curl up. Keep a basin of water at hand so that any of the bath which may get on the fingers may be washed off immediately, in which case it will not stain them. When the paper has floated long enough raise one corner with a glass rod, catch it with a clothes-pin and hang it on a string to dry, attaching a small bit of blotting paper to the lower corner to catch the drop. When dry roll the paper on a stick with the sensitive side out to straighten it. Then cut the paper to the proper size and store it between sheets of blotting paper which have been saturated with a solution of bi-carbonate of soda and dried. In this way sensitive paper may be kept for a week or two.

Before printing the paper is put into a box with a lid and fumed for ten minutes. Print usually by direct sunlight until the print is darker than the finished photograph is desired. Trim them by cutting around the edge of a trimming glass. I got the trimming glasses cut at a glass store, and smoothed the edges with sandpaper, which makes them cost but little. After trimming wash the prints well; then tone them, for which purpose I find the following bath to work well:

Tri-chloride of gold	1 grain.
Carbonate of soda	10 grains.
Water	10 ounces.

Dissolve the 15 grains of gold, which comes in a small bottle, in 15 drachms of water, and in preparing the above bath pour out one drachm of the solution. The bath should be used immediately and works quicker if heated to 100 or 120 degrees Fahr. Keep the old bath, adding fresh chemicals each time before using.

After toning, fix the prints with:

Hyposulphite of soda	1 pound.
Ammonia	2 drachms.
Water	½ gallon.

Leave them in this bath for about ten minutes, then wash thoroughly. I usually leave them in water over night, with the water running slightly part of the time, after which I wash each one thoroughly as I take it out. Partly dry the prints with blotting paper and mount them with "Parlor Paste." The arrangement which I devised to keep them from curling up when drying is shown in Fig. 1.

The albumenized paper contains sodium chloride, which is changed by the bath to silver chloride, some free nitrate remaining on the paper. After printing the picture consists of silver, silver subchloride, and silver albumenate. In toning gold is substituted for part of the silver, possibly in the following way:

$$3Ag_2Cl + AuCl_3 = 6AgCl + Au.$$

OUTFIT.

The articles which a beginner will need for taking photographs 5 × 8 are:

For Taking and Developing the Negative.

1 Darlot lens, No. 1	$15.00
1 Camera box	20.00
1 Tripod	2.50
1 Frame for paper holders	2.00
½ Dozen paper dry plate holders	2.50

1 Gossamer focusing cloth	$1.00
1 Ruby lantern	2.75
3 Japanned iron trays, 5 × 8	.75
1 4-ounce measuring glass	.35
1 Nest of 3 beaker glasses, 2 to 4 ounces	.45
3 20-ounce glass bottles	.30
1 ½ gallon glass bottle	.15
2 4-ounce wide mouthed glass bottles	.40
1 Glass stirring rod	.10
1 Glass funnel	.20
1 10-ounce bottle for intensifier	.10
2 Camel's hair brushes	.20
1 "Granite ware" washstand set	5.75
1 pound Neutral oxalate of potash	.50
1 pound Photosulphate of iron	.06
5 pounds Hyposulphite of soda	.25
1 dozen Dry plates	1.75
2 ounces Bichloride of mercury	.25
2 ounces Chloride of ammonia	.30
6 ounces Retouching varnish	.50
1 box Calcined flour (Bigelow's)	.35
Total	$58.46

Silver Printing.

1 Porcelain tray, 10 × 12	$1.20
1 Argentometer	.60
1 Thermometer	1.00
1 pair Scales	1.00
1 20-ounce Bottle, glass stopper, for silver bath	.25
1 16-ounce Bottle, for old toning bath; 1 1½-ounce Bottle, for chloride of gold	.10
1 Fuming box (any old box will do)	0.00
4 Printing frames	2.60
3 Trimming glasses 3.8 × 6.1, 3.8 × 7.65 and 4.4 × 7.33	.40
2 Iron pans, "granite ware," for toning and fixing	.40
1 Glass funnel	.25
1 Flat brush, for pasting	.25
1 Sponge	.25
1 1-drachm Measuring glass	.25
2 ounces Nitrate of silver	1.70
1 dozen sheets Albumenized paper	.90
15 grains Chloride of gold	.60
½ pound Carbonate of soda	.06
1 pint stronger Ammonia water	.40
1 pint white Parlor paste	.35
½ dozen sheets Blotting paper	.40
¼ pound Absorbent cotton	.35
50 Cabinet mounts	.50
25 Panel mounts	.60
100 mounts, 5 × 8, cut to order	1.00
Total	$15.41
Add total for negatives	58.46
Total cost of outfit	$73.87

This is as cheap an outfit as I will recommend for satisfactory results on a 5×8 plate.

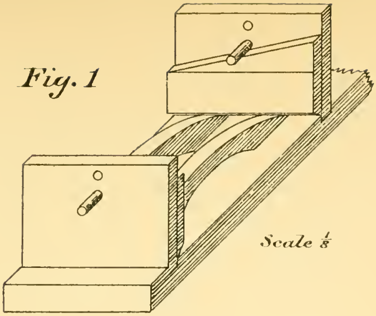
Not including the cost of my surveying camera I suppose I have spent over $200, which includes a $52 lens and some material for sundry experiments.

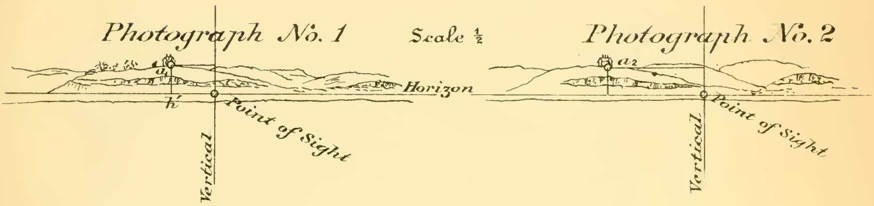
APPLICATIONS.

The following are some of the uses to which the art can be put by an engineer:

In visiting engineering works, completed or under construction, much has frequently to be learned in a short time. A few photographs of the general plan, interesting details and machinery used in construction, showing methods of doing work, would be of incalculable value. The advantage in an engineer's being able to take the views himself instead of buying them consists in his being able to get just what he wants without being bothered with that which can be of no value to him. Besides, it will frequently happen that there is no professional photographer near.

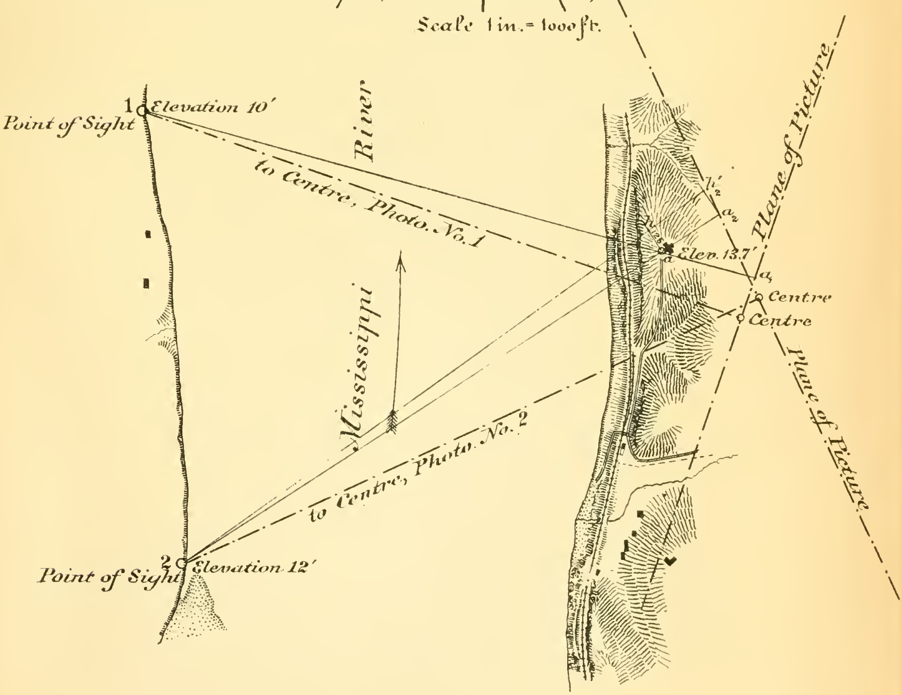
Fig. 1





Map, Bushberg, Mo.

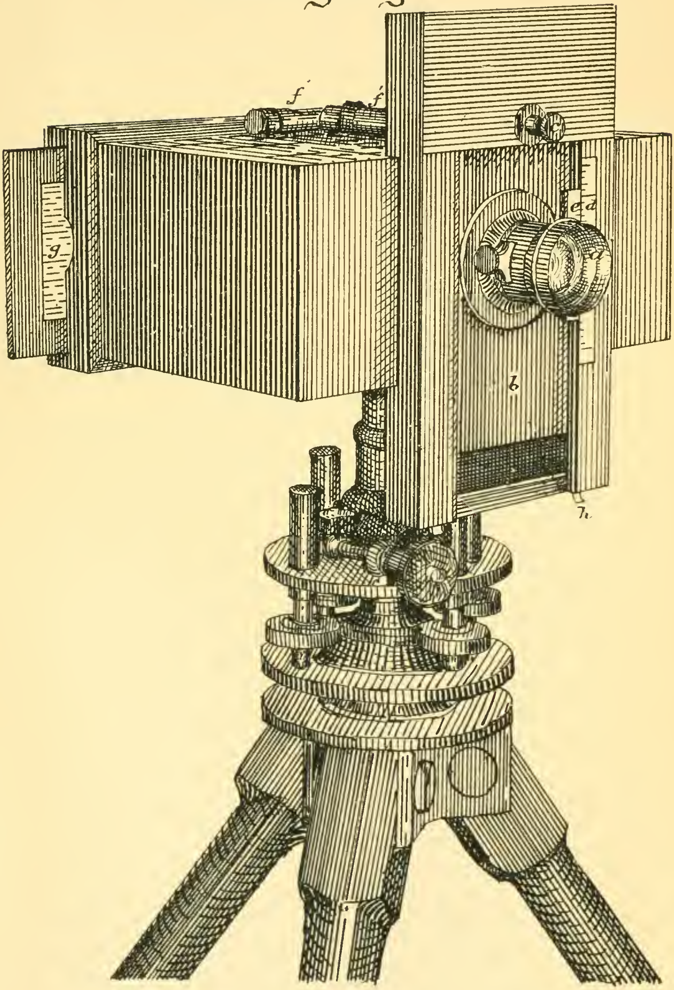
Scale 1 in. = 1000 ft.



N. B. The distance ah (125) is the elevation of the point a above station 2

Fig. 2

Surveying Camera



If an engineer is in charge of construction and wishes to report progress either to a chief or board of directors, a photograph is the most accurate and trustworthy method of showing the exact condition of the work. In this case a boy could easily be taught to do the drudgery connected with developing and printing.

In case of accident to railway property, such as a washout or landslide, a wreck caused by collision, fallen bridge, tornado, earthquake or otherwise, a photograph is the quickest way of reporting the extent of damage and condition of the wreck.

Drawings can be quickly photographed and reduced in this manner to a small scale, and made of uniform size, so that they will occupy but little room and still all the details be sufficiently well preserved to make working drawings from them if necessary. These photographs are also exceedingly convenient for an engineer who is superintending the building of machinery, saving him the bother of carrying a large drawing.

Blue prints can, of course, be made from negatives as readily as from tracings, and for many purposes are preferable to silver prints.

If a blue print be made of a machine or other object, and a pen and ink drawing be made on top of it, the blue may be afterward washed out or destroyed by immersing the picture in a saturated solution of bicarbonate of soda, which in about a minute causes the blue to disappear, leaving only the black ink lines on a white ground. Wash it carefully in water and dry ; after which it may be photo-engraved and set up with ordinary type in printing a catalogue, or elsewhere. The best ink I have ever found for the purpose is "Higgins' American Drawing Ink" ("waterproof.") The Moss Engraving Company, of New York, use silver prints and wash out with cyanide of potassium, which is obviously inferior to the above method, which I have never seen described, and it may be new.

If autolithographic ink be used instead of Higgins' the drawing can be transferred immediately to the stone without washing out the blue. The accompanying view of my surveying camera was made in this way. For this work paper prepared for autolithography should be used.

A negative can be taken from a tracing or drawing on thin paper directly by contact instead of using the camera, prints taken from it giving black lines on a white ground in silver printing, or blue lines on a white ground in blue printing. For a large drawing the negative and chemicals for developing would be expensive.

SURVEYING WITH THE CAMERA.

This being a strictly engineering use of photography, and having been but little used, if at all, in this country, and not much any where, is perhaps the most interesting to those present or who will read this paper. I will, therefore, now give a description of the surveying camera which I have had made for experimental work next summer in connection with the United States survey of the Missouri River ; also the general principles and method of application, reserving the details for another paper, which, if you desire it, I will read at some future time, when I hope to know more about the subject.

In this work the dry plate must of course exactly take the place of the ground glass used in focusing, both of which are in the plane of the pic-

ture. It is obvious this plane must be made accurately vertical, so that all vertical lines may appear so in the photograph, and that all objects may be projected on the horizon by parallel lines. That the horizon may be accurately determined some line, as the one through the centre of the ground glass, must be capable of being made truly horizontal. To accomplish both these ends the small levels, shown at f and f' in Fig. 2, are placed on top of the camera box, the one being horizontal and parallel to the ground glass, the other perpendicular to it. The back of the box must be rigid and the focusing done by moving the lens, which is easily accomplished, since for distant objects but little change is necessary. The dry plates should, on the score of economy and convenience, be long and narrow, those I use being $2\frac{1}{2} \times 8$.

The lens should be so fixed that it can be moved up or down, for taking bluffs or mountains above the point of sight, or valleys below it.

To accomplish this the lens a is attached to a slide b, moving vertically. A clamp screw is shown at c. The slide carries a vernier e which in connection with the fixed scale d shows how far the lens has been moved. The zero of the scale is determined by bringing the lens to the point where objects in the horizon are projected on the horizontal line through the centre of the ground glass. The slide b is held against the front of the camera box by brass springs, one of which is under the clamp c and the end of another is shown at h. The ground glass for focusing is shown at g, partly withdrawn.

The distance from the optical centre of the lens to the ground glass is accurately determined by measuring a base line in front of the camera, measuring the distance to the base line, and the length of the image or distance between the extremities as shown on the ground glass. Any change in the focal distance is measured by a scale on the side of the lens, not shown in the drawing. One of the smaller stops should be used to sharpen up the picture.

If photographs be taken with the surveying camera from two known stations, and the direction of the point of sight be measured with a transit or by means of a compass attached to the camera, the position of each object which can be seen in two pictures can be determined on the map both horizontally and vertically. The method of placing the photographs in position and locating objects is, I think, so well shown in the accompanying map that it need not be described here.

The map is part of an experimental survey I have just made at Bushberg, 25 miles below St. Louis, on the Mississippi River. The draughtsman should work directly from negatives on account of the greater accuracy and distinctness of detail. The accuracy of the gelatine film on glass is so great that Dr. Eder was not able to discover any change, from developing and fixing, although by the method used he could have detected a variation of $\frac{1}{6000}$ in the distance.

By this method of surveying the plane table is virtually brought into the office, and the topographer is at both stations simultaneously without being bothered by sun or wind.

The chief difficulty arises from aerial perspective, or the fact that distant objects appear as masses, it being hard to distinguish details. The photograph should therefore be taken when the air has little smoke or

haze in it, and if possible when the sun shines on the back of the instrument. For nearly inaccessible mountain regions, where the air is so clear that distant objects appear very close, I think the surveying camera will be invaluable. Its peculiar adaptation to military purposes, where it is important to reduce the time of the field work, need not be pointed out.

Besides the above use of photography there are many critical moments arising in engineering practice as where Capt. Abney, Corps of Royal Engineers, tested the value of torpedoes by instantaneously photographing the column of water thrown up by the explosion.

The most wonderful achievement in photography is perhaps that of M. Marey, a French savant, who has successfully photographed a flying bird by the use of a photographic revolver in the form of a fowling piece aimed at the bird. Twelve pictures were taken successively, each being exposed $\frac{1}{700}$ of a second, gelatino bromide plates being used which were capable of taking pictures with an exposure of $\frac{1}{1500}$ of a second. By putting the pictures in a phenakistiscope of Plateau the flying of a bird could be observed.

The following books may be recommended in the order given. "Photographic Amateur," by J. Traill Taylor. New York, Scoville Manufacturing Co., 50 cents. "A Treatise on Photography," by W. de Wiveleslie Abney. New York, D. Appleton & Co., $1.50, belonging to the "Text-books of Science." "Modern Dry Plates," by Dr. J. M. Eder, and "Silver Printing," by H. P. Robinson and Captain Abney. New York, E. & H. T. Anthony & Co., 1881, 75 cents each. "The Chemical Effects of Light and Photography," by Dr. Hermann Vogel. New York, D. Appleton & Co. "International Scientific Series," $2.

PHOTOMETRIC TESTS.

By Thos. D. Miller, Member of the Engineers' Club of St. Louis.

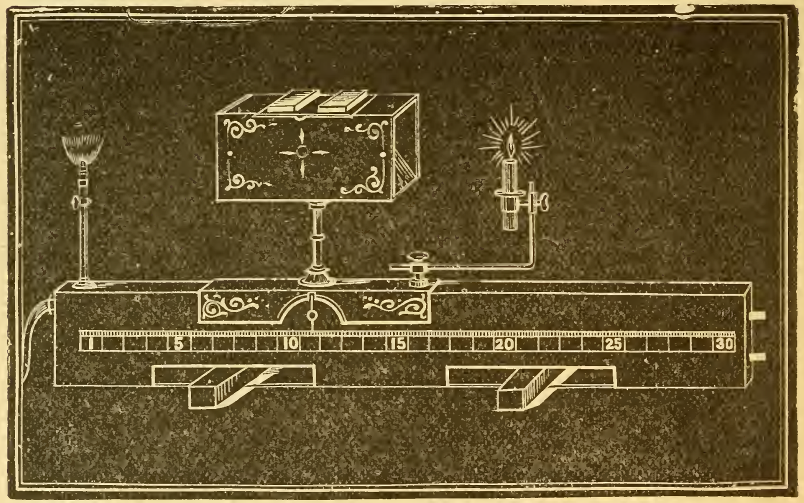
[Read March 26, 1884.]

The photometer may be defined as an instrument for the comparative measurement of the light emitted from two luminous bodies.

The necessity of such an instrument asserted itself about the period of the introduction of gas for domestic lighting. The first we know of the use of a photometer was in the latter part of the eighteenth century, when Count Rumford invented his method now known as the shadow test. This was accomplished by causing two shadows, made respectively by the two lights being compared, to fall on a white surface, and by shifting either light until the shadows were of equal intensity, and measuring their respective distances from the surface where the shadows fell, the comparative intensity of the two lights was obtained. This instrument was subsequently greatly improved, but it has been superseded by the Bunsen photometer, and has been modified by King, Lethby, Church and Mann, and Evans.

The Bunsen Photometer, in its simplest form, consists of a bar graduated by the formula $X = \frac{100}{\sqrt{n} + 1}$, where X = distance from the stand-

ard light, say a candle, to the point to be marked with a given number of candles n, and 100 is the distance between lights; a socket for the candle at one end of the bar; a burner for the gas at the other end; a pair of balances to weigh the candle; a governor to regulate flow of gas; a meter to measure same, and a clock to time observations. The readings are then obtained by moving a paper disc to and fro upon the graduated bar, which disc is held in a small box with three openings in it, two in opposite sides to admit the light from the two sources and the third for the observer to see the disc, which is facilitated by two small mirrors placed in such manner that both sides of the disc are simultaneously seen. This disc is composed of two parts, the centre portion being translucent and the surrounding portion opaque, or *vice versa*. If the disc be held between the eye and the source of light the translucent portion will appear light and the opaque will appear dark, while, if the eye be placed on

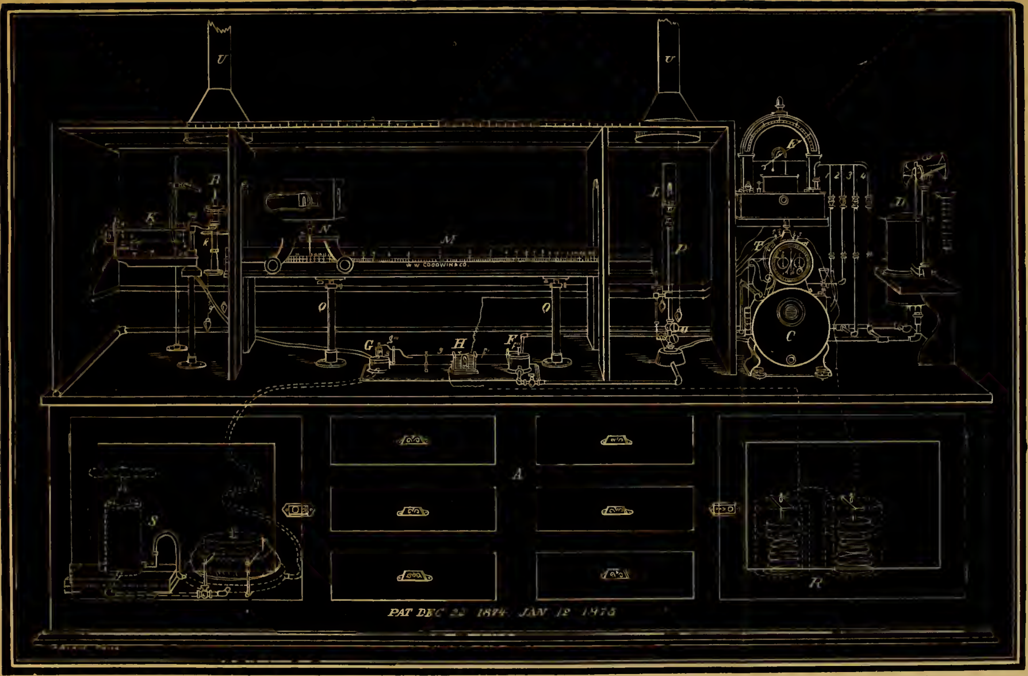


60″ PLAIN PHOTOMETER.

the same side of the disc as the source of light, the reverse is true. By this it will readily be seen that, if the disc be placed between two lights and moved until both sides appear the same, we have a point where the intensity of the two lights is equal, also, according to the sensitiveness of the disc, the observation will be more or less accurate.

The Church and Mann photometer carries the candle holder attached to the disc box at the uniform distance of 10 inches from it. The advantage is that it gives a better illumination on the candle side of the disc, and permits closer readings, the divisions being larger. The great objection to this photometer is that in shifting the candles an irregular and abnormal consumption of sperm is liable to occur.

The above described photometers require a dark room in which to operate. The Evans photometer does away with the dark room and con-



Bunsen—Letheby 60 Inch Bar Photometer, with Goodwin's Electrical Attachment Arranged to Extinguish Gas and Candle, and Stop Meter and Clock, when normal quantity of Gas or Sperm has been Consumed on Expiration of time, for which Instrument may be set.

sists of a box large enough to inclose candles and burner, with the disc fixed and the candles movable.*

The quality of the photometric test will be governed by :

1. The accuracy of the meter.
2. The correctness of the standard of comparison ; and,
3. The skill of the observer.

The wet meter is generally used because of its accuracy and facility of adjustment. The greater number of errors of photometry are doubtless due to a fluctuation in the standard of comparison and to personal errors. The standard of comparison in this country and England is candles consuming at the rate of 120 grains per hour of standard English sperm. In France the standard of comparison is Colza oil.

A great variety of oils have been suggested as a substitute for candles. Mr. King says in his work : "As far as our present knowledge extends there is every reason to believe that a lamp standard is more accurate than the use of candles, although for portability, cleanliness, and facility of manipulation the latter cannot be surpassed. Admitting the durability of a lamp as a standard. the question for settlement is what oil is the most suitable. * * * We conclude in favor of sperm oil. The special suitability of this oil over all the others arises from the following considerations ; it is obtained as a natural product and is not submitted to any chemical treatment ; it will burn more evenly and with less clogging to the wick than any of the vegetable oils ; it is not liable to variations in character which necessarily attend vegetable oils expressed from seed of different ages and from different soils ; lastly, its unusually low specific gravity affords a ready test for purity, excluding adulteration with the commoner oils, all of which possess a higher specific gravity than that of sperm."

The photometer room should be large enough to admit of a free circulation of air and should be well ventilated near floor and ceiling, but in such manner as to admit no foreign light.

The candles and gas should be allowed to burn several minutes before the test begins, to insure a normal consumption of sperm and perfect flow of gas.

There need be no correction for gas, for with care the flow of gas can be regulated to such a nicety that the error will be less than $\frac{1}{120}$ of a cubic foot. The supply of gas, however, should not be altered except at the beginning of each minute, and only once in each minute. The correction for sperm is a simple proportion. The resultant candle power is inversely as the amount of sperm consumed. This is only approximally true, and the test should be rejected when the two candles consume 5 grains more, or 5 grains less than they should in 10 minutes. As the consumption of sperm will vary during the test it has been recommended that the candles be weighed at the end of each minute, but a better result will be obtained by taking two or more observations each minute, thus securing a better average of both candles and gas. The writer has suceeeded in taking four readings per minute with accuracy. In twenty-five ten minute tests, and twenty

*A *complete* discussion of this subject will be found in King's work on "Coal Gas," to which the writer acknowledges his indebtedness.

observations in each test, the average of the readings in the first half minute was 17.84 candles and of the second half minute was 18.09 candles, showing a difference of .25 candles, while the greatest difference between the average of the readings of the first and second half minutes in any one test was .72 candles and the least was .11 candles. These differences are partially due to the irregular flow of gas caused by imperfect centering of the drum of the meter, and partially to the irregular consumption of sperm.

As the volume of gas varies very greatly with temperature and atmospheric pressure it is obvious that it is desirable to reduce all results to one common standard pressure and temperature. These are taken at 30 inches of mercury and 60 degrees Fahrenheit, and the reduction is accomplished by the following factor:

$n = \dfrac{17.64\,(h-a)}{460+t}$ in which

h = height of barometer inches.
t = temperature Fahrenheit, and
a = tenison of aqueous vapor at t degree. If
v = volume at t degree and h inches and
V = the corresponding volume at 30 inches and 60 degrees, then
$V = v\,n$.

This factor n is calculated for every two degrees and $\frac{1}{10}$ inch and tabulated for ready use.

The burner which is used as a standard in England and our eastern cities is Sugg's "D" burner for coal gas, and Bray's patent tip for water gas. In St. Louis the Laclede Gas Light Company is supplied with Sugg's "D" burner at the inspector's office and Sugg's "C" burner at the works. The St. Louis Gas Light Company is supplied with both "C" and "D" burners. The City Gas Inspector's office is supplied with "C" burners. That it is essential in comparing two photometric tests to know whether they are taken with the same burner is very apparent from the table below. Sugg's "C" burner has been taken as a standard, and all other burners tested are set down in their direct ratio to the standard, after reducing all results to one common unit which we will call foot candle. For example the "C" burner consuming 5 feet produces 16.50 candles then $\frac{16.50}{5} = 3.30$ foot candles, and the Bray tip consuming 16.8 feet produces 69.89 candles, then $\frac{69.89}{16.8} = 4.16$ foot candles or 126 per cent. of the value of the sandard. With this explanation it is a very simple matter to determine what burners are the best and under what conditions they yield the best results. In the selection of burners the question to be considered is whether diffused or concentrated light is desired. It will be seen that the smaller burners give a much smaller foot candle power than the larger ones, therefore to concentrate a great number of small burners will waste a great deal of gas that could be utilized by using fewer and larger burners. All these tests were made upon a 100-inch bar photometer with two standard candles. The burners were all new and were furnished by The Fay Gas Fixture Company and Mr. John Sobolewski, inspector of St. Louis Gas Light Company.

TABLE OF TESTS OF GAS BURNERS.

No. of test.	NAME OF BURNER.	Size of burner.	Rate of consumption per hour, feet.	Burning pressure. Tenths inch.	Candle power.	Foot candles.	Per centum of standard.	REMARKS.
		Feet.						
1	Sugg's "C" standard........	5	5	½	16.50	3.30	100	
2	Common 40-hole Argand....	5	5	1½	14.20	2.84	86	
3	Improved Argand, contracted chimney	5	4.9	1½	15.68	3.20	97	.. This burner smokes with more than 5 feet of gas.
4	Suggs' "D" English standard	5	5	1½	20.80	4.16	126	
5	Bray's patent tip............	18	16.8	8	69.89	4.16	126	
6	"E. H." tip Young Am. pillar	4	4	5½	13.84	3.46	105	
7	" " "	4	5	7½	17.15	3.43	104	
8	" " "	5	5	11	18.00	3.60	109	
9	" " "	5	6	16½	22.38	3.73	113	
10	" " "	5	6.5	20	26.39	4.06	123	
11	" " "	6	7.9	17½	28.91	3.66	111	
12	" " "	6	7	15	24.71	3.53	107	
13	" " "	6	6	11	23.34	3.89	118	
14	Young American brass tip..	2	3	20	7.71	2.57	78	
15	" " "	2	2	10½	4.88	2.44	74	
16	" " "	3	3.5	18	10.39	2.97	90	
17	" " "	3	3	14	9.69	3.23	98	
18	" " "	4	4.5	17	14.71	3.27	99	
19	" " "	4	4	14	12.52	3.13	95	
20	" " "	5	5.5	17	19.41	3.53	107	Hissing sound.
21	" " "	5	5	14	19.45	3.89	118	
22	"E. H." tip com. brass pillar	½	3.5	19	4.02	1.15	35	
23	" " " "	½	2	9	3.24	1.62	49	
24	" " " "	½	1	5	.92	.92	28	
25	" " " "	½	0.5	3	.51	1.02	31	
26	" " " "	1	4.6	20	6.67	1.45	44	
27	" " " "	1	2	7	3.96	1.98	60	
28	" " " "	1	1	3	2.41	2.41	73	
29	" " " "	2	6.5	20	12.41	1.91	58	
30	" " " "	2	4	11	10.28	2.57	78	
31	" " " "	2	2	4	5.22	2.61	79	
32	" " " "	3	7.8	18	22.39	2.87	87	
33	" " " "	3	5	12	16.50	3.30	100	
34	" " " "	3	3	4	9.39	3.13	95	
35	" " " "	4	11.6	16	36.30	3.13	95	Hissing sound.
36	" " " "	4	7	8	27.23	3.89	118	
37	" " " "	4	4	3	15.84	3.96	120	
38	" " " "	5	10.8	16	35.96	3.33	101	
39	" " " "	5	7	7	28.42	4 06	123	
40	" " " "	5	5	4	18.95	3.79	115	
41	" " " "	6	10 6	16	34.98	3.30	100	Hissing sound.
42	" " " "	6	9	13	34.74	3.86	117	
43	" " " "	6	6	7	25.74	4.29	130	
44	" " " "	8	11	16	38.83	3 53	107	
45	" " " "	8	8	6	31.68	3.96	120	
46	" " " "	10	17.6	10	51.04	2.90	88	
47	" " " "	10	10	4	43.90	4.39	133	
48	" " " "	12	16.7	8	60.12	3.60	109	
49	" " " "	12	12	5	54.24	4.52	137	
50	"E." tip " " "	2	4.5	19	7.29	1.62	49	
51	" " " "	2	2	8	3.70	1.85	56	
52	" " " "	3	5 2	19	9.93	1.91	58	
53	" " " "	3	3	9	7.14	2.38	72	
54	" " " "	4	7.5	17	18.52	2.47	75	
55	" " " "	4	4	8	11.60	2.90	88	
56	" " " "	5	8.2	17	24.35	2.97	90	
57	" " " "	5	5	9	16.50	3.30	100	
58	" " " "	6	9.4	16	28.86	3.07	93	
59	" " " "	6	6	7	20.76	3.46	105	
60	Scotch tip...................	6	4.8	19	13.92	2 90	88	
61	"E. H." tip super heater ...	6	5.7	19	21.60	3.79	115	
62	Duplex tip............	5	6	18	16.26	2.71	82	Old burner.
63	" "	5	5	13	13.20	2.64	80	" "

Pressure in main after passing meter, 21 tenths.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JANUARY 16, 1884 :—A regular meeting of the Boston Society of Civil Engineers was called this evening, President Thomas Doane in the chair and eight members present.

A quorum not being present no business was transacted.

Mr. S. E. Tinkham reported from *Van Nostrand's Eclectic Engineering Magazine* for the year 1883, calling attention to the following :

In the April, May and June numbers, "Recent Hydraulic Experiments in the Ganges Canal in Northern India."

In the May number, "The American Practice of Warming Buildings by Steam," by Robert Briggs.

In the August number, "Formula for Pillars Applied to Tests Made at the U. S. Government Machine at Watertown, Mass."

In the November and December numbers, "The Proportions of Arches Determined from French Practice," also "A New Method of Sinking Shafts in Watery Running Ground."

Mr. F. L. Fuller reported from *Engineering News* of 1883, calling attention to the following:

In the number dated July 21, "The Broken Reservoirs at Knoxville, Tenn." July 28, "The Tools of the Pyramid Builders." August 25, "Agreement for Grading, Contract Between the American Construction Company, of New Jersey, and the South Pennsylvania Railway Company" ; also, "The Depth and Velocity of the Niagara River." September 20, "The Divining Rod."

Mr. L. F. Rice reported from the *American Architect* for the year 1883, calling attention to "The Results of Experiments on the Transverse Strength of Wooden Beams Made at the Massachusetts Institute of Technology." Mr. Rice also alluded to some curious constructions in wooden buildings remodeled by him.

H. L. EATON, Secretary.

FEBRUARY 20, 1884 :—A regular meeting of the Boston Society of Civil Engineers was held this evening at 7:50 P. M., President Thomas Doane in the chair and fifteen members present.

The record of the last meeting was read and approved.

On motion of Mr. F. P. Stearns it was voted :

That the Society have a dinner at the annual meeting in March.

On the motion of Mr. Henry Manley it was voted :

That a committee, to consist of three persons, be appointed by the chair to make all necessary arrangements for the annual dinner.

The chair appointed as that committee: Messrs. Henry Manley, L. Frederick Rice, Fred. Brooks.

On motion of Mr. Henry Manley it was voted :

That the sum of fifty dollars be appropriated for the general expenses of the annual dinner, to be expended at the direction of the committee, all bills to be approved by the President in the usual manner.

On motion of Mr. F. P. Stearns it was voted :

That a nominating committee of five be chosen by nomination at large to pre-

sent a list of candidates for officers of the Society for the ensuing year, three names to be presented for each office.

The Committee nominated were Messrs. Fred. Brooks, F. P. Stearns, S. E. Tinkham, E. W. Howe, L. F. Rice.

Mr. C. M. Wilkes was proposed for membership, recommended by Messrs. H. A. Carson and E. W. Howe.

Mr. J. R. Robinson read a paper on "The Safety-Seam Steam Boiler."

[*Adjourned.*] H. L. EATON, Secretary.

ANNUAL MEETING.

MARCH 19, 1884 :—The Annual Meeting of the Boston Society of Civil Engineers was held at Young's Hotel at 6 o'clock P. M., Vice-President Edward S. Philbrick in the chair, and forty-two members present.

The record of the last meeting was read and approved.

On motion of Mr. Fred. Brooks it was voted that Mr. E. W. Howe be appointed Auditor *pro tem.*, in the absence of the Auditor elect.

The Special Committee on the Introduction of the Metric System presented its Annua Report, and on motion the report was laid on the table until late in the evening.

The Annual Report of the Government of the Society was presented and accepted, and on motion was ordered to be printed.

The Special Committee on the Introduction of the Metric System, as chosen by nomination at large, is constituted as follows : Frederick Brooks, Charles H. Swan, Clemens Herschel.

The Special Committee on the Preservation of Timber was continued as at present constituted.

On motion it was voted the Special Committee on Class-List of Engineering Books in the Boston Public Library be nominated by the President at his convenience.

On motion it was voted that the Committee to solicit advertisements for the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES be nominated by the President at his convenience.

A letter was read from Mr. Benezette Williams, Chairman of the Board of Managers of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, referring to the action of the Western Society of Engineers in voting to withdraw from the Association. After general discussion on the advantages and benefits derived and the necessity of continuing the JOURNAL by Messrs. Brooks, Herschel, Manley, Carr, and Rice, the following resolution was presented :

Resolved, That the Boston Society of Civil Engineers is heartily in favor of a continuance of the Association of Civil Engineering Societies and of its JOURNAL.

That we invite all local societies in North America not already members to join the Association.

Mr. Clemens Herschel moved that the Secretary be instructed to send a copy of this resolution to all local societies in North America. The yeas and nays were called for, and the motion was passed, yeas 32, nays 0.

The Committee appointed to nominate a list of candidates for officers reported in print as follows:

President:	Vice President:	Secretary:	Treasurer:	Librarian:
T. Doane,	H. A. Carson,	H. L. Eaton,	W. H. Bradley,	F. W. Hodgdon,
C. Herschel,	D. Fitzgerald,	C. S. Parsons,	E. C. Clarke,	C. W. Kettell,
G. L. Vose.	C. W. Folsom,	F. O. Whitney.	H. Manley.	A. F. Noyes.
	E. S. Philbrick.			

On motion it was voted that the Society proceed to ballot for officers for the ensuing year.

On motion it was voted that a committee of three be chosen by nomination at large to receive, sort and count ballots.

The Committee nominated were William Jackson, John E. Cheney and Albert F. Noyes.

The Society then proceeded to ballot with the following result:

President, George L. Vose. Vice-President, L. Frederick Rice.
Secretary, Horace L. Eaton. Treasurer, Henry Manley.
Librarian, Charles W. Kettell.

Mr. Edward W. Howe was appointed Auditor by vote.

On motion of Mr. Fred. Brooks it was voted that an assessment of six dollars be levied on resident members of the Society.

On motion it was voted that the report of the Committee on the Introduction of the Metric System be taken from the table and printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Mr. C. M. Wilkes was elected a member of the Society.

Proposals for membership were received from Mr. Seth Perkins, recommended by Messrs. E. C. Clarke and F. P. Stearns, and from Mr. Henry H. Carter, recommended by Messrs. E. C. Clarke and F. P. Stearns.

[*Adjourned.*] H. L. EATON, Secretary.

ANNUAL DINNER.

The second annual dinner of the Boston Society of Civil Engineers was held at Young's Hotel, Boston, March 19th, 1884, at 7:30 P.M.

After the annual meeting had adjourned the Society and invited guests, to the number of fifty, were conducted to an adjoining hall, where an elegant and bountiful repast had been prepared. An hour and a half were spent in enjoying the dinner and in conversation.

There were present, as guests of the Society,

General F. A. Walker,	Edward Atkinson,
Major C. W. Raymond,	J. J. R. Croes.

In the absence of the President and Vice-President, Mr. Ernest W. Bowditch presided at the table.

The company was addressed by Mr. Edward Atkinson on the permanency of the results of civil engineering and the necessity of the broadest training in preparatory schools.

Mr. J. J. R. Croes, Treasurer of the American Society of Civil Engineers, extended the congratulations of that Society, and the regrets of its officers, that they were prevented from attending the dinner by previous engagements.

Mr. Henry Manley, of the Committee of Arrangements, read letters from President Elliot, of Harvard University, C. Frank Allen, Albuquerque, N. M., and Edward C. Cabot, President of the Boston Chapter of the American Institute of Architects.

Mr. Francis A. Walker, President of the Massachusetts Institute of Technology, referred to the aims and purposes of that institution as a training school for the application of the principles of civil engineering in the practice of the profession.

Major Charles W. Raymond, of the U. S. Engineer Corps, alluded to the interests of the U. S. Government in the control and improvement of the harbors of Eastern Massachusetts, and the improvements made by the national government in Boston Harbor during the past year.

Mr. Clemens Herschel referred to the advantages of a technical education and its influence in raising the standard of engineering as a profession, and as fitting an engineer to fill positions outside the line of direct practical work.

Mr. Frederick Brooks described the natural resources of Mexico and the condition of her people.

Professor George L. Vose, President-elect of the Society, referred to the common interests of technical schools and engineering societies and the assistance such societies afford students in technical schools.

Addresses were also made by H. A. Carson, D. Fitzgerald, L. F. Rice and C. F. Folsom.

H. L. EATON, Secretary.

ANNUAL REPORT OF THE GOVERNMENT OF THE BOSTON SOCIETY OF CIVIL ENGINEERS FOR THE YEAR ENDING MARCH 18, 1884.

During the last Society year two members have been taken away by death. Frank A. May was lost in the wrecking of the steamer City of Columbus on the morning of January 18, and Clarence W. Lunt died of consumption at his home, on February 22.

One member has withdrawn and five new members have been added during the year so that our net gain in membership during the year has been two and our total membership now stands at one hundred and thirteen.

The finances have been managed during the year with the usual economy in the matter of rent and general expenses.

On account of the want of a sufficient number of written papers the JOURNAL OF THE

Association of Engineering Societies has not been issued every month, and in two cases two months have been combined into one number. The expenses in this direction have therefore been somewhat reduced from those of last year, and all our papers or transactions have been printed.

There is to the credit of the Association in its treasury the sum of $225.05, a pro rata proportion of which is to the credit of the Boston Society.

The Treasurer's report is presented herewith in detail; from it we learn that the property of the Society is as follows :

Permanent funds in bonds and cash	$1,497.00
Current funds in bank	298.79
Making a total of	$1,795.79

Permanent Funds.

Amount March 21, 1883, bonds, $1,200; cash, $185	$1,385.00
" " 11, 1884, " 1,200; " 297	1,497.00
Increase during the year	$112.00

Current Funds.

Receipts for year ending March 21, 1883	$426.48
" " " " " 11, 1884	576.05
Increase	$149.57

Expenses.

Expenses for year ending March 21, 1883		$663.07
" " " " " 11, 1884		417.96
Decrease during the year		$245.11
Increase of income		149.57
Gain in current funds the last year over previous year		$394.68
Gain in permanent funds for year ending March 21, 1883	$185	
" " " " " 19, 1884	112	
Gain in permanent funds		73.00
Net gain in transactions		$321.68

The Government recommends an assessment for the ensuing year of $6.00.

The library as at present located is not of much value for reference. It is, however, accumulating books which will be of value whenever the Society shall find itself in possession of a *home* where they can be properly arranged and made easy of access.

The books are now stored in boxes.

The Society has met in its regular monthly meetings, on each month of the year except on July and August. There have been no special meetings. The average attendance has been seventeen and one-half.

Thomas Doane, President.
Edward S. Philbrick, Vice-President.
Horace L. Eaton, Secretary.
Henry Manley, Treasurer.

Abstract of Treasurer's Report for the Year Ending March 19, 1884.

Receipts.

Balance on hand at commencement of year			$140.70
Assessment for current year, 87 members	@$6.00	$522.00	
Non-resident dues " " 9 "	@ 3.00	27.00	
" " " coming " 4 "	@ 3.00	12.00	
			561.00
Interest on current balance			15.05
			$716.75

Receipts Permanent Fund.

Cash on hand, as per last report	$185.00
Entrance fees	72.00
Interest on bonds	40.00
	$297.00

Disbursements.

Association of Engineering Societies		$172.50
Rent		45.00
Salary Secretary		50.00
Binding		19.75
Printing		38.85
Postage and stationery		11.26
Periodicals		29.55
Annual dinner		47.05
Packing case		4.00
Cash on deposit		298.79
		$716.75

Funds of the Society in the hands of the Treasurer.

One Burlington & Missouri Railroad bond		$600.00
One Republican Valley Railroad bond		600.00
Permanent fund, cash	$297.00	
Current fund, cash	298.79	
		$595.79
		$1,795.79

By vote of the Society the income of invested funds and money received for entrance fees, is to be added to a permanent fund, and not used for current expenses.

HENRY MANLEY, Treasurer.

REPORT OF THE COMMITTEE ON THE METRIC SYSTEM OF WEIGHTS AND MEASURES, PRESENTED AT THE ANNUAL MEETING OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, MARCH 19, 1884.

The Committee on the Metric System of Weights and Measures presents this report in pursuance of the vote passed March 17, 1880, that "The Committee on the Metric System shall gather, from time to time, and present to the Society, all attainable information relative to the progress toward the introduction of the metric system into this country and the world at large."

Uniformity Wanted.

One of the causes of the progress referred to is the unifying spirit which characterizes the world to-day ; and your Committee would draw attention to the potency of this cause by mentioning a few of its effects.

International association for systematizing business is seen in matters scientific, professional, commercial, political, statistical, literary, religious and charitable. The General Postal Union comprises all the advanced nations, and transmits correspondence at a very low price to the remote corners of the globe. The Latin Union gives a uniform coinage to several of the central and southern countries of Europe. The Scandinavian Union gives a uniform coinage to Sweden, Norway and Denmark. An international code of marine signals has been adopted by the maritime nations.

Some recent movements for introducing uniformity have attracted the active interest of our own profession. In the United States last fall new standards of time were adopted, belonging to meridians of longitude differing by intervals of one hour, or 15°, and reckoned from a prime meridian or zero-point in a foreign country; this reform was accomplished by the action of the managers of our railroads. They have also been striving to secure uniformity in their shops, as was ably set forth by Mr. Octave Chanute in a paper on "Uniformity in Railway Rolling Stock," published in the Transactions of the American Society of Civil Engineers for September, 1882, and reprinted in the *Railroad Gazette* in January, 1883. The latter part of the paper gave an interesting history of the long struggle of railroad companies and others to get a system of screw-threads adhered to in the U. S. A., so that bolts and nuts might be interchangeable; money has been freely spent for the purpose, for to quote one paragraph, "It appeared that the master car-builders had all encountered the trouble, annoyance and expense resulting from the lack of uniformity in screw-threads, and were confident that a general reform in this respect would save hundreds of thousands of dollars annually to the railroads of the country." A full account of the matter was contained in the report of the Sixteenth Annual Convention of the Master Car-Builders, and a brief and simple summary appeared in the *Railroad Gazette* for July 20, 1883. Great companies like the Erie Railroad can change their practice in regard to screw-threads, it was made evident; and they are glad to do so if that is necessary for the sake of uniformity.

The prevailing tendency toward uniformity, of which the foregoing are a few of the simplest manifestations, has brought about, prominently among other influences, the

adoption of the metric system of weights and measures, by all but a very few of the principal nations of the world during the last hundred years, and is now steadily pushing it forward in those few. If this tendency shall continue, ancient, local and peculiar weights and measures will be driven out of use ; but if, on the other hand, concert of action among men should cease, if our ships should be destroyed, our railways abandoned, our telegraph wires cut, our newspapers suppressed and our post-offices shut up, then the United States might go on using national weights and measures not recognized elsewhere ; then she might, in Texas and California, keep dealing in varas, fanegas and arrobas, forbidden in Spain and Mexico ; then she might tolerate forever in the Mississippi Valley the arpent, prohibited in France and her colonies ; then she might maintain indefinitely in the Northern and Eastern States her Winchester gallon and bushel, abandoned in Great Britain about sixty years ago, and more recently abandoned in Canada ; and her apothecaries' weight, based on the Troy ounce, abandoned by the British Pharmacopœia about twenty years ago : then she might preserve for posterity in the Philadelphia mint, as the only weight her Congress has ever declared a standard, her Troy pound abandoned in Great Britain about six years ago.

Great Britain.

For the purpose, it may be presumed, of affording a seasonable warning to prepare for the impending change, it has been made the duty of your committee to present such particulars as it has been able to gather in regard to the recent progress of the metric system.

Last fall when the meridian of Greenwich was adopted by the International Geodetic Conference sitting at Rome as the base for reckoning standard time and longitude, there was coupled with their vote the suggestion that Great Britain should take a further step toward international correspondence of weights and measures. The London *Graphic* of October 27, 1883, said: "The Geodetic Conference recommends that for the future all seamen should regard Greenwich as their astronomical Mecca, hoping that in return England will agree to join the Metrical Convention of 1875. It must be admitted that in the matter of decimals, England has stuck in an old world rut, and that all, or almost all, the other nations have gone ahead of her. This is what a member of the London Chamber of Commerce assures us, and he also asserts that the retention of our insular system of coinage, weights, measures and calculations, is really detrimental to our continental trade."

In the address of Sir Wm. Thomson, President of Section A British Association for the Advancement of Science, at their Jubilee Meeting, in 1881, as reported in *Engineering*, vol. 32, p. 321, for September 23, 1881, he referred to the metric system, parantheticaly, in giving a metric equivalent, as something "to which in all scientific and practical measurements we are irresistibly drawn, notwithstanding a dense barrier of insular prejudice most detrimental to the islanders."

In the same number of *Engineering* (p. 306) was a paper read by W. H. Preece, F.R.S., before the British Association, about the sizes of small screws used in electrical apparatus. He complained that for want of uniformity, interchangeability for making repairs was impossible, and supplying one country with materials manufactured in another occasioned great difficulty. He said : "The exchange of apparatus between this and continental countries is now so general that the adoption of the French decimal metrical system is well worth serious consideration. This is felt so much that in nearly every table of wire gauges the dimensions, both in parts of inches and meters are given. The adoption of the meter as the unit length would secure adoption of the gauge abroad. The use of the inch as unit leaves us in that singular insular position to which Sir Wm. Thomson pointedly referred in Section A the other day." He proposed a system of sizes, based on the new centimeter gauge, recommended by the Society of Telegraph Engineers in December, 1879. The largest diameter in his table was 6.4 mm., or 0.252 in. It was independent of the Whitworth system, generally adopted in England. He hoped the subject might be referred to a committee of the British Association.

A committee of twelve was appointed, among whom were Sir Joseph Whitworth and Mr. W. H. Preece, and they reported to the August, 1882, meeting of the British Association that they recommended decimals of an inch for expressing the dimensions of small screws, because the inch is the unit established in Great Britain, and that they recommended the Whitworth form of thread; but that they were not unanimous on all the questions involved, and they asked to be reconstituted and to have an appropriation

They also presented at length, though they did not adopt it, the Swiss system of small screws tabulated below. They said: "The subject of uniformity in screws has been very warmly taken up by the Société des Arts de Genève, which appointed a committee in December, 1876, who, after assiduous labors, issued a report in 1878. The system proposed by them has been very fully described by Professor Thury in two pamphlets published in Geneva," referring to Systematique des Vis Horlogères, Geneva, 1878, and Notice sur le Système des Vis de la Filière Suisse, Geneva, 1880. The Swiss committee based their system upon a study of a great variety of existing screws from a number of factories: their dimensions were plotted on a diagram, and a mathematical curve was fitted to them in order to obtain a simple expression of their average proportion. The diameter is in the new system made equal to 6 multiplied by the six-fifth power of P, in which P is the pitch. The system started with a screw of 1 mm. pitch and 6 mm. diameter, and each succeeding number has a pitch .9 of the next greater. The form of thread is triangular, with an angle of about 47½ degrees; the depth is .6 of the pitch; the top is rounded with a radius 1-6 of the pitch; the bottom .2 of the pitch.

SWISS SYSTEM OF SMALL SCREWS.

No.	Pitch. Mm.	Pitch. Thousandths of an inch.	Diameter. Mm.	Diameter. Thousandths of an inch.	Threads per inch.
25	.072	2.8	.25	10	357.
24	.080	3.1	.29	11	323.
23	.089	3.5	.33	13	286.
22	.098	3.9	.37	15	256.
21	.11	4.3	.42	17	233.
20	.12	4.8	.48	19	208.
19	.14	5.3	.54	21	189.
18	.15	5.9	.62	24	170.
17	.17	6.6	.70	28	152.
16	.19	7.3	.79	31	137.
15	.21	8.1	.90	35	124.
14	.23	9.	1.00	40	111.
13	.25	10.	1.2	46	100.
12	.28	11.	1.3	52	91.
11	.31	12.	1.5	59	83.
10	.35	14.	1.7	67	71.4
9	.39	15.	1.9	76	66.7
8	.43	17.	2.2	86	58.8
7	.48	19.	2.5	97	52.6
6	.53	21.	2.8	111	47.6
5	.59	23.	3.2	126	43.5
4	.66	26.	3.6	142	38.5
3	.73	29.	4.1	162	34.5
2	.81	32.	4.7	183	31.2
1	.90	35.	5.4	208	28.6
0	1.00	39.	6.0	236	25.6

The American Watch Co., and the American Watch Tool Co., of Waltham, Mass., adopted the metric system for their measures ten or fifteen years ago, from which it may be inferred that our countrymen would be as favorably disposed toward the Swiss as toward the British Association series of small screws.

The Sellers screw threads came into conflict with the metric last fall in a railroad shop in the city of Mexico. The company was laying French iron pipe with screw-joints, and required to cut some pieces and cut threads at the places where they were divided for connecting them with full length pipes having French threads. The master-mechanic had made it a rule that only taps and dies of the Sellers system generally used in the United States should be allowed in the shop; and he was reluctant to permit the use of a metric thread at variance therewith.

With the increase of international business such instances as the foregoing will be multiplying every day. The inconvenience of sending British manufactures with Whitworth screw-threads and American manufactures with Sellers screw-threads into metric countries, or of exchanging them between Great Britain and the United States, may naturally be expected to lead in time to action for establishing international uniformity, similar to the action that our railroad companies have already taken for

establishing national uniformity. Much study has recently been given to this subject by engineers in Germany, on account of the recent introduction there of the metric weights and measures. Some of them wished to adopt as an international standard the Whitworth system in British inches, which has been extensively used in Germany; others wanted a new system in metric measures. In the second French edition, dated December, 1880, of "Le Constructeur," by Professor Reuleaux, of the Berlin Polytechnic School, were a dozen octavo pages (pp. 205–218), illustrated by nine diagrams, carefully discussing the Whitworth system, the Sellers system, and the application of the metric measures to screw-threads, from which it appeared that the German engineers had not then come to an agreement.

The merits of the Sellers system have led to its ready adoption in the United States and carried it into some places in Germany. Mr. Coleman Sellers in some instructive papers which he published several years ago referred to the general use of these screw-threads as if he thought it would prove an almost insurmountable obstacle to the introduction of the metric weights and measures into the United States. Now supposing, for the sake of argument, that the Sellers screw-thread system based on the British inch should continue to be the U. S. standard and should, moreover, be adopted throughout the world, that would no more prevent the introduction of the metric weights and measures for other purposes than our adherence to a nomenclature of nails as 3-penny, 4-penny, 6-penny, etc., prevented our abandoning the pence, shillings and pounds sterling of our forefathers and adopting a decimal currency with Latin names, dime, cent and mill.

In England the Board of Trade is now authorized to provide metric standards for the purposes of science or of manufacture, but not of trade. Among the British sessional papers last received here is the report by the Board of Trade, dated August 3, 1881, on their proceedings under the Weights and Measures Act, 1878; the following is an extract: "During the past year no applications have been made to this department by local authorities with reference to the metric system, although its use for the purposes of science and manufacture is increasing. Questions have arisen as to the legal use of metric weights by manufacturers, who are also traders, as local inspectors are not provided with standards of the metric system, by which they may verify weights of metric denominations for the use of traders."

In the British Pharmacopœia, to facilitate the use of the metric system in volumetric estimations, a table is appended to the description of each volumetric solution, in which the quantities to be used are represented in grams and cubic centimeters, as well as in grain and grain-measures; and comprehensive tables are added to the book for showing the relations existing between the British and the metric weights and measures.

United States.

In 1883, as predicted in the report of your committee a year ago, was published the 15th edition of the United States Dispensatory, a hand-book which the physician is constantly referring to, as the surveyor is constantly referring to his book of logarithms. It is based on the United States Pharmacopœia, which was treated of in former reports of your committee. In this edition of the Dispensatory for the first time metric equivalents are given throughout for the doses and other expressions of quantities, a most practical step toward the introduction of the metric system. The following statement is made under the head of "Metric Prescriptions" (p. 1798): "Of late years since the more general use of the metric system, prescriptions written according to this method have been frequently employed, especially in sections of our country inhabited by those who are accustomed to use the system, which is now almost exclusively employed in Europe."

Now that many people travel abroad and carry their physicians' prescriptions with them it may be worth knowing that the ounce weight used in the U. S. Pharmacopœia is different from the ounce weight used in the British Pharmacopœia; that the fluid ounce, fluid drachm and minim capacity-measures used in the U.S. Pharmacopœia are different from the fluid ounce, fluid drachm and minim used in the British Pharmacopœia; but that the gram and cubic centimeter used in the U. S. Pharmacopœia are exactly the same as the gram and cubic centimeter used in the British Pharmacopœia and throughout the world.

As to our own profession, Mr. Adams gave, at the December meeting of the Society, a detailed statement of his use of the metric system in his office in this city for the last four years, which has been published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING

SOCIETIES for September and October, 1883 (Vol. 2, pp. 322-6). It is the general practice of mining engineers in this country to make their assays in metric weights; the assay offices have gram weights. As long as they shall continue to make reports in ounces to the ton, so long will they be at some trouble to translate their results. One way that they accomplish it is to make an assay of 29 1-6 grams of ore; then every milligram of precious metal corresponds to one Troy ounce in a Massachusetts ton of 2,000 avoirdupois pounds, for $\frac{2,000 \times 7,000}{480 \times 1,000} = 29\ 1\text{-}6$. In addition to other government surveys noticed in previous reports of your committee the triangulation and the precise leveling of the Mississippi River Commission have been done in meters; some of the current and sediment observations have been tabulated in both metric and old denominations, and in the report on the topographical operations both meters and feet are found.

The publication of conversion tables continues. In the Consular Report, just now issued by the State Department at Washington, are a set of tables by M. Thirion, a clerk in our Consulate at Paris. The Ordnance Department has printed, in Ordnance Notes, No. 192, dated 15th May, 1882, some tables by Lieut. Rogers Birnie, carried out to a great many decimal places. Prof. R. H. Thurston last year reprinted most of them, with the addition of some British tables, as an appendix to his "Materials of Engineering," and has had them issued also in the form of a separate volume. William Sychelmoore, of Philadelphia, has very recently printed some tables by Wm. A. G. Emonts, C. E., which are very compact, and give only about as many decimals as might be wanted for business purposes.

There is to be found, though rarely, in the United States a tailor who uses the centimeter in his measurements; for that unit is more convenient than the inch for fitting clothing to the human body. Such measures usually have many cumbersome halves and quarters, because dimensions to the nearest inch are not exact enough. There are halves and quarters, too, in the inch series of numbers designating the series of manufactured articles of clothing like hats, collars and socks. The substitution of the centimeter as the unit does away with most of these fractions; for a measurement to the nearest centimeter is generally exact enough in that class of business. Other reasons which may contribute to make the metric system especially acceptable there are that fabrics used for clothing are very largely imported from Europe, and that fashions also originate in Europe.

Statistics of American commerce more recent than were contained in former reports of your committee can now be compiled as follows from the annual report on Commerce and Navigation for the year ended June 30, 1881, issued by the Bureau of Statistics of the U. S. Treasury Department:

Imports of merchandise produced in countries whose governments have adopted the metric system	$348,347,158	
Domestic merchandise exported to countries whose governments have adopted the metric system	303,356,827	$651,703,985
Imports of merchandise produced in countries that have weights and measures neither metric nor British	81,845,231	
Domestic merchandise exported to countries that have weights and measures neither metric nor British	42,215,703	
Domestic merchandise measured in gallons and bushels exported to countries that use British imperial weights and measures	148,925,300	272,986,234
Imports of merchandise produced in countries that use British imperial weights and measures	212,472,239	
Domestic merchandise not measured in gallons and bushels exported to countries that use British imperial weights and measures	389,428,117	601,900,356
Total merchandise imported	642,664,628	
Total domestic merchandise exported	883,925,947	
Sum of imports and exports		1,526,590,575

The conclusion to be drawn from this is that the adoption of the metric system throughout the United States would facilitate about 43 per cent. of her foreign commerce, which now subjected to inconvenience by differences in weights and measures, that in about 39 per cent. where there is now international uniformity it would introduce an inconvenience which would continue until the adoption of the metric system by Great Britain and her possessions, and that to the remaining 18 per cent. it would not be of consequence in this respect.

About fifteen million dollars' worth of the imports produced in metric countries was shipped from Great Britain to the United States, and an amount not worth reckoning (probably about two million dollars' worth) exported to Great Britain was to be consumed in metric countries. Great Britain, whose commercial supremacy is now one of the most conspicuous facts of trade, so far as it is in countries using the metric system that she invests her capital, and so far as it is their goods that her ships are carrying all over the world, is enlisted in the propogation of the metric system.

Mexico and Argentine Republic.

It appears that a postponement of two years has been made in the date of putting into effect the law for the exclusive use of the metric system in Mexico, which was quoted in the report of your committee a year ago. Whether this is correct or not, it will certainly require many years for the system to be brought thoroughly into use by all the people of that country for reasons mentioned in the former report.

In the Buenos Ayres *Herald* of January 1, 1884, was a notice of a meeting of produce merchants and brokers, who unanimously resolved that cereals ought to be sold by the metric system, beginning with the 1st of February, and that an attempt should be made to abolish the use of all other measures in the grain business; also that the introduction of the metric system in the purchase and sale of all other produce of the country prior to the time fixed by law, January 1, 1887, was to be recommended. The columns of the newspaper showed the use in land measurement of metric measures largely, but not exclusively, and in the grain business the use chiefly of the fanega, but partially of metric weight.

It is the sad duty of your Committee to say that one of their number, Mr. Clarence W. Lunt, has been recently removed by death. Mr. Lunt was always much interested in the work of this Committee, and his loss is greatly deplored. This is not the place for a memoir of Mr. Lunt, but his genial presence will always be remembered by your Committee.

The pressure of business incident to the change of residence of Mr. Fteley from this city to New York, and to the departure of the chairman of your Committee for Europe on professional business, would have rendered it impracticable for your Committee to report to the Society at this time, were it not for the courtesy of Mr. Frederick Brooks, formerly chairman of this Committee, who has kindly written the greater portion of this report.

Respectfully submitted,

CHARLES H. SWAN, Chairman.

ENGINEERS' CLUB OF ST. LOUIS.

APRIL 9, 1884:—The Club met at Mercantile Library at 8 o'clock, twenty members being present. The following new members were elected: E. A. Engler, N. W. Perkins, Jr., K. Tully, J. A. Vail and J. A. Ockerson.

James W. Hill, member of the Club, read a paper on "The Wind-Mill of To-Day and Its Uses."

This paper was discussed.

In accordance with a resolution the president appointed Robert Moore, J. B. Johnson and D. C. Humphreys a committee to arrange for an excursion of the Club at an early day.

A vote of thanks was tendered to Mr. Hill for his paper.

[*Adjourned.*] J. B. JOHNSON, Secretary.

APRIL 23, 1884:—229th Meeting.—The Club met in the Physical Laboratory of Washington University at 7:45 P. M., thirty-five members and fifty or sixty visitors being present.

The minutes of last meeting were read and approved.

A communication was received from the Secretary of the American Society of Civil Engineers in response to an inquiry from the Secretary of this Club, stating that a full set of their transactions up to 1880 (since which time the Club h received them) had been forwarded to this Club.

The Secretary reported that they had arrived, and he was instructed to have them bound. A vote of thanks was heartily and unanimously adopted for this handsome gift on the part of the Board of Direction of the American Society.

An invitation was read from Mr. N. O. Nelson, President of the Mercantile Club, offering the free use of their club-house in which to hold our meeting This generous offer came unsolicited and without any previous knowledge on the part of any member of this Club. Action on this invitation was laid over till next meeting.

Moved, that a committee of three be appointed to prepare a communication to be submitted to the Boston and Cleveland clubs for their amendment or endorsement, and then to be forwarded to the Western Society at Chicago, in regard to their recent action in withdrawing from the Association.

The President appointed C. Shaler Smith, Henry Flad, and Robert E. MacMath on this committee.

The Committee on Excursion reported, favoring an excursion to Crystal City by boat some time in May. Major Ernst had kindly offered the use of one of his steamers for this purpose. The report was received and the committee continued.

The following names were submitted for membership: Chas. Foster, by E. D. Meier and H. G. Tidemann; Hubert Taussig, by E. D. Meier and C. M. Woodward; Dr. Wellington Adams, by J. B. Johnson and D. C. Humphreys.

Dr. Adams was then invited to read a paper on "The Evolution of the Electric Railway," to which he responded, showing working models and stereopticon views. He exhibited his own patented device for applying an electric motor to the axle of a car wheel, and the subject was generally discussed by the Club till a late hour.

A vote of thanks was tendered Dr. Adams for his paper, and the Club adjourned.

J. B. Johnson, Secretary.

WESTERN SOCIETY OF ENGINEERS.

April 1, 1884:—The 183d meeting was held at 4 P. M., Vice-President Randolph in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Wright, for Committee on Transportation, reported that this Committee had a short paper for this meeting, and a paper for the next meeting by Mr. Randolph, on "The National Electric Signal."

The Secretary read a letter from Mr. Henry Manley, Chairman of Committee of Arrangements, inviting the officers and members of this Society to attend the annual dinner of the Boston Society of Civil Engineers.

It was voted that the thanks of the Society be presented to the Boston Society for this invitation.

Mr. Wright read a paper discussing an article by Mr. Samuel McElroy, in the *Railroad Gazette* of March 28, 1884, under the head of "Track Problems." After reading of the paper the discussion was continued, most of the members present taking part.

It was voted that the paper read by Mr. Wright should be printed.

[*Adjourned.*] L. P. Morehouse, Secretary.

April 15, 1884:—The 184th meeting was held at 4 P. M., Vice-President Randolph in the Chair.

The minutes of the preceding meeting were read and approved.

Mr. Lotz, for Committee on Machinery, announced that at the next meeting he would present Plans and Detail Drawings for Weehawken Elevator, to be built for the West Shore & Ontario Terminal Co., at Weehawken, N. J.

The Committee on Order of Proceedings, through Mr. Cooke, presented a partial report, recommending that no business be transacted at the first meeting in the month.

The report was accepted and the matter referred back to the committee.

The Secretary presented a photograph portrait of Mr. George F. Kirby, the first one received under the recent resolution of the Society, asking for photographs of members.

It was voted that a committee of three be appointed to consider, and report at the next meeting, upon the matter of extending some courtesies to the American Institute of Mining Engineers at its meeting in Chicago, May 27.

The Chair appointed Messrs. Jones, Wright and Cregier as this committee.

The resignation of Mr. Robert Forsyth, as a member, was read and accepted.

Papers were presented by Mr. Randolph on the National Electric Signal, and by Mr. I. C. Chesbrough, read by Mr. Benezette Williams, on the Location of the Northern Pacific Railroad Across the Rocky Mountains.

It was voted that these papers should be printed.

[*Adjourned.*] L. P. Morehouse, Secretary.

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1. In accordance with a resolution adopted at the 182d meeting, members are requested to send cabinet photographs of themselves to the Secretary for presentation to the Society.

2. Members whose address or names are incorrectly given in list of members lately published in the Journal, will please send corrections to the Secretary for *Errata*.

3. Members who have not yet paid the amounts they subscribed toward furnishing the Society rooms are hereby reminded of these subscriptions.

4. The attention of members whose dues are delinquent is respectfully called to Circular dated February 12.

(P. O. address, I. C. R. R. Chicago, Ill.) L. P. Morehouse, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

February 12, 1884:—A regular meeting was held, President Holloway in the chair. The minutes of the last meeting were read and approved. The petitions of G. L. Sterling, H. G. Welty and John R. Patterson were read and referred to Committee on Membership.

The Committee appointed November 13, 1883, on change of Constitution so as to admit Associate Members, reported, and were discharged.

Resolution by Mr. Rice :

Resolved, That there be a committee appointed to make a report describing the paving material used in various cities, together with such information as to its usefulness as can be obtained from the experience of other cities or by actual test.

The following amendment to the Constitution was offered by Mr. Rice:

Resolved, That the following amendment be substituted for Section I. of the Constitution, to be applied to all future applicants for admission after its passage:

Section 1.—Persons shall be eligible to membership who have pursued one of the following professions for a livelihood for the space of five years or more, two years' allowance being made in favor of graduates of scientific schools, namely :

Civil Engineers, Mechanical Engineers, Mining Engineers, Architects, Astronomers, Geologists, Analytical Chemists. Signed :

Walter P. Rice,
Hosea Paul,
John L. Cully,
C. H. Burgess,
C. O. Avery.

Resolution by Mr. Laman :

Resolved, That the Chair appoint a committee to nominate officers for the ensuing year, to be elected at the Annual Meeting in March. The President suggested that blank tickets be passed to the members, thus enabling them to express their choice to the Committee, which was heartily endorsed. The Chair appointed the following members a Nominating Committee : J. J. Laman, W. P. Rice, G. A. Hyde, E. H. Martin.

The Committee reported two tickets for the members to choose from, which was accepted.

For President—J. F. Holloway; John Whitelaw.

Vice-President—B. F. Morse; W. P. Rice.

Corresponding Secretary—A. Mordecai; John L. Culley.

Recording Secretary—M. W. Kingsley; F. C. Bate.

Assistant Recording Secretary—S. H. Baker; F. C. Bate.

Member Board of Publications—M. E. Rawson; C. H. Burgess.

Treasurer—G. A. Hyde; N. P. Bowler.

Resolution by Mr. Dorring:

Resolved, That a Committee of nine members be appointed (of whom the President shall be one) to make arrangements for the Annual Meeting.

The following named persons were appointed : J. F. Holloway, H. C. Thompson, W. P. Rice, Charles Latimer, N. P. Bowler, M. L. Deering, J. Whitelaw, A. Mordecai, E. H. Jones, W. R. Warner.

Mr. Mordecai offered the following resolution :

Resolved, That until otherwise ordered by the Club, the Recording Secretary, his assistant, the Treasurer, and the members of the Board of Managers of the Association of Engineering Societies shall be excused from the payment of the annual dues during the time they occupy such offices. Adopted.

Resolution by Mr. Rawson :

Resolved, That the thanks of this Club be, and are hereby extended, to the Hon. M. A. Foran, for a donation to this Club, through Mr. Charles Latimer, of thirteen volumes of the United States Coast Survey for the years 1870 to 1882, and that the Secretary be directed to acknowledge the same.

The following amendment to the By-Laws was presented :

Resolved, That the first clause of Article III., Section 2, of By-Laws, be changed so as to read : Applications for membership shall be made to the Committee on Membership through the Recording Secretary.

(Signed.)
John Whitelaw.
Isaac Whitehead.
E. H. Jones.
C. O. Arey.
J. Enright.

On motion, the Club took recess to Tuesday evening, February 26, when the discussion of the papers announced for this evening will be taken up.

M. W. Kingsley, Recording Secretary.

February 26, 1884:—Meeting called to order by the President at 8 p. m. An interesting paper on the "Construction of Frame Buildings," by Mr. C. O. Arey, was read.

The verbal report of Mr. Bowler, Chairman of the Committee on Arrangements for the Annual Meeting, was made to the Club.

Discussion of Mr. Martin's paper on "Some Statistics of the Pumping Engine of the Period" was indulged in by many of the members.

A vote of thanks was tendered to Mr. C. O. Arey for his interesting paper.

[*Adjourned*]. F. C. Bate, Assistant Secretary.

ANNUAL AND REGULAR MEETING.

MARCH 11, 1884:—The meeting was held at the rooms of the Windsor Club, President Holloway in the chair. The minutes of the last meeting were read and approved.

The Chair appointed S. T. Wellman, E. H. Jones and A. Swazey, Tellers, to count the vote for officers for the ensuing year.

The Treasurer made a very gratifying report as follows :

Amount on hand March 10, 1883	$175.25
Collections to date	722.25
Total collections	$897.50
Expenses during year to date	430.62
Balance on hand to date	$466.88

G. A. HYDE.

Report read and approved.

The Committee on Membership reported favorable on the petition of J. L. Sterling, H. G. Welty and John R. Patterson, and the Secretary was instructed to cast the favorable ballot of the Club for their election, which was done. The President then delivered his annual address.

The following resolution by J. Whitelaw was adopted :

Resolved, That the thanks of this Club are hereby tendered to Hon. M. A. Foran, our Representative in Congress, for his kind remembrance of our Club, by the presentation of Vols. I. and II. of the Report of the U. S. Board on "Testing Iron, Steel and other Metals." Also the Report on "Commerce Between the United States and Mexico."

The proposed amendment to the Constitution and By-Laws was postponed to another meeting.

The tellers reported the following named persons elected as officers for the ensuing year :

President, J. F. Holloway.
Vice-President, B. F. Morse.
Corresponding Secretary, A. Mordecai.
Recording Secretary, M. W. Kingsley.
Assistant Secretary, F. C. Bate.
Treasurer, G. A. Hyde.
Member of Board of Managers of the Association of Engineering Societies, M. E. Rawson.

After the serving of refreshments, the remainder of the evening was spent in a very enjoyable manner in listening to speeches from the various members.

[*Adjourned.*] M. W. KINGSLEY, Secretary.

APRIL 8, 1884 :—Regular meeting ; Pres. Holloway in the chair. Minutes of last meeting read and approved. The amendment to the By-Laws as presented at the February meeting was adopted with the exception of inserting the word Recording before the word Secretary.

On motion of Mr. Jones, the Treasurer was authorized to settle the shortage in bills of the Committee for Annual Meeting, also bill due Mr. Claflin.

Letters were read from Hon. M. A. Foran and Col. J. M. Wilson.

On motion of Mr. Paul, the discussion on amendment to the Constitution was postponed to the next regular meeting.

The paper for the evening, by B. F. Morse, on the Settlement of Masonry at West End of Viaduct, was listened to with interest and called forth an earnest discussion on foundations. Mr. Morse was tendered a vote of thanks. The President then announced the standing committees for the ensuing year :

Publication and Library—M. E. Rawson, A. H. Porter, S. J. Baker.

Membership—J. Whitelaw, W. P. Rice, S. T. Wellman.

Civil Engineering and Surveying—J. H. Sargeant, C. H. Burgess, C. G. Force, J. L. Culley, Hosea Paul.

Mechanical Engineering.—A. Swasey, E. H. Jones, E. H. Martin, A. Brown, T. D. West.

Railroad Engineering—Chas. Latimer, H. M. Claflin, H. C. Thompson, H. F. Dunham, J. J. Laman.

Architecture—J. Eisenmann, J. W. Richardson, C. O. Arey, O. D. Leisenring, F. T. Barnum.

Subjects Pertaining to Scientific Pursuits—W. B. Wood, W. R. Warner, Geo. Bartol, C. W. Paine, J. B. Merriam.

The Programme Committee is elected from the other committees—one from each committee. The Secretary was instructed to notify the members of the different committees of their appointment, and request them to meet at the Club Rooms, Tuesday evening, April 14, to elect the Programme Committee.

The President announced that the Cleveland Rolling Mill Co. extended an invitation to the Club to visit its works in the southeastern part of the city.

The invitation was accepted and the following committee appointed to make arrangements: Mr. Claflin, Mr. Morse, Mr. Culley and Mr. Hyde. On motion President Holloway was added to the committee.

Correspondence regarding the Saratoga engine was read, but was discussed very little, owing to the lateness of the hour.

Hon. Amos Townsend presented the Club with three volumes of "Tests of Iron, Steel and other Metals."

[*Adjourned to meet April* 22, 1884.]

M. W. Kingsley, Recording Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

ON THE FILTRATION OF CERTAIN SALINE SOLUTIONS THROUGH SAND.

By Wm. Ripley Nichols, Member of the Boston Society of Civil Engineers.

[Read April 16, 1884.]

It is well known that certain porous substances, notably bone coal, possess the power of removing from solution organic coloring matters as well as other substances of animal or vegetable origin. This action in some cases seems to be simply an adhesion of the particles of the dissolved substances, and, by proper treatment, they may be recovered unchanged. In other cases, however, chemical change takes place, and oxygen, absorbed from the air or held in solution in the liquid, acts upon the organic matter and either destroys it or alters essentially its character. This property, which bone coal possesses to a remarkable extent, is possessed to a much less extent by wood charcoal and by other porous substances. Moreover, the researches of Graham showed that animal charcoal possessed to a limited extent the power of removing saline substances also from their solutions. We should naturally expect that, if a substance like pure silicious sand possessed this property of absorption at all, it would be only to a very slight extent, and this is the result of experience.

It has been shown by a great number of experiments and analyses made by the Rivers Pollution Commission in England, by Piefke in Berlin, and by other observers, that the action of a common sand filter upon the *organic matter* dissolved in ordinary surface waters, although appreciable, is still very slight,* but Piefke† has shown that, in the passage of such surface water for a considerable distance through a porous stratum of sand and gravel, the *organic matter* is gradually destroyed, owing to the action of the dissolved oxygen.

What, now, is the effect of filtration through sand on the *dissolved saline substances* which may be in the water?

* See the author's Filtration of Potable Water. New York, Van Nostrand, 1879.

† Die Boden Filtration. Berlin, 1883.

It is a somewhat widely-spread popular idea that if solutions of salt or other saline substances be filtered through a sufficient quantity of ordinary sand, the saline substances are retained to a certain extent by the sand, so that the filtered liquid contains appreciably less than before filtration. This idea has been combatted many times, but it reappears every now and then. The purpose of the present paper is to show that, for all practical purposes, the action of a sand filter on dissolved saline substances amounts to nothing, unless it may be in the case of some substances which are susceptible of chemical change under these conditions. Thus, it may happen, under certain circumstances, that a water containing bicarbonate of lime in solution may, by simply passing through sand, give up some of its carbonic acid and deposit crystals of carbonate of lime in the pores of the filter, but the action is inappreciable with the ordinary saline substances, as a type and example of which we will take common salt.

In the first place, if we study the results of the numerous analyses made and published by the Rivers Pollution Commission of Great Britain, we shall find that almost invariably the amount of combined chlorine (or of chlorides) in the filtered and unfiltered water is either exactly the same or varies within the limits of analytical error.* The analyses of the Spree water at Berlin, filtered and unfiltered, show the same thing,† and I have myself made examinations, small in number in comparison with those of the Rivers Pollution Commission, but which have led to the same results. This is, in fact, the nearly universal testimony of those who have examined into the matter ; viz., that, in the practical operation of a sand filter, any chlorides contained in the water pass through the filter unchanged, and this is true, also, of most soluble salts. There, is, however, some conflicting testimony. A number of years ago, in a discussion on filtration which took place at a meeting of the Institution of Civil Engineers, a Mr. H. Shield exhibited tables showing the effect of sand and of vegetable charcoal upon water from the River Thames. He claimed that a sand filter, even after 120 hours' action, retained 22 per cent. of the chlorine originally present in the water.‡ In view of the large number of analyses which have accumulated since the publication of these results, I think we can have no hesitation in concluding either that the results are inaccurate or else that the samples of water do not fairly represent the same water before and after filtration. I may further state that it is generally known and agreed among agricultural chemists that the chlorides are not retained in the soil, but pass into the drainage waters.

Although there is, as has been said, a great deal of published evidence, enough, in fact, to show that for practical purposes filtration through sand will not remove substances like common salt, it seemed desirable to perform some independent experiments on the subject, and if possible to repeat such experiments of previous observers as have led to ideas which we believe to be false. It is stated by Professor Way,§ in a paper "On the Power of Soils to Absorb Manures," that Berzelius found upon filter-

* Sixth Report: Water Supply of Great Britain. London, 1876, p. 217.

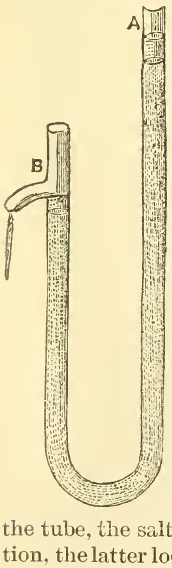
† Piefke: Die Boden Filtration.

‡ Proc. Inst. Civil Engrs., XXVII. (1867–68), p. 28.

§ Journal Royal Agricultural Society, XI. (1850–51).

ing a solution of common salt through sand that the portions which thus passed were quite free from saline impregnations. I have been unable to find the original statement of Berzelius. Matteucci alludes to it in these words :* "Another more conclusive fact is that cited by Berzelius. Salt water in filtering through a long tube full of sand issued completely deprived of or less strongly charged with salt." Matteucci himself is quoted as confirming the experiment of Berzelius, but he performed only one experiment with chloride of sodium, using a tube 8 meters long, filled with sand. He found that the density of the solution introduced at the upper extremity of the tube was to that of the liquid which issued from the lower extremity as 1 : 0.91. He says, "But it must be added that this difference in density does not remain exactly in this proportion; after a certain time, the saline solution issues from the tube with the same density that it had before its introduction." He also obtained an opposite result, using a solution of carbonate of sodium and passing it through a tube 3 meters long, filled with sand. The density of the liquid issuing from the tube was to that of the original liquid as 1.005 : 1. Since we are in total ignorance as to the character of the sand employed, it does not seem that much weight should be laid upon these experiments. It is easy to see how the carbonate of sodium might increase in density, owing to its solvent action on the sand, which was probably not pure silica.

In Ure's Dictionary there is an article by Normandy on the purification of salt water, in which an experiment is described which is, in all probability, the original experiment of Berzelius. The details are given with sufficient definiteness to admit of its repetition. He says :



"Fresh water can be obtained from sea water in two ways; the one by distillation, the other by passing it through a layer or column of sand, or of earth, of sufficient thickness or length. In effect, if sea water be poured at *A* (Fig. 1), in a pipe 15 feet high, and full of clean, dry sand, the water, which will at first flow at *B*, will be found pretty fresh and drinkable; but as the operation is continued, the water which flows at *B* soon becomes brackish, the brackishness gradually augmenting, until, in a very short time, the water which flows at *B* is actually more salted than that poured at *A*, because the latter dissolves the salt which had been first retained by the sand, which must then be renewed or washed with fresh water, a process evidently useless for the purpose in question. This phenomenon, according to Berzelius, is due to the interstices between the grains of sand acting as capillary tubes; and as, at the beginning of the operation, the effect depends more on the attraction than on the pressure of the liquid poured in one of the branches of the tube, the salt is partly separated from the water which held it in solution, the latter lodging itself into the interstices of the sand, and filling

* Leçons sur les Phénomènes Physiques des Corps Vivants. Paris, 1847, p. 29.

them. If, when the mass of the sand is completely wetted, a greater quantity of sea water is poured upon it, the weight of the said sea water first displaces and expels the fresh water ; but as soon as the interstices of the sand have thus been forcibly filled up with sea water, the water flowing at *B* becomes more and more salted ; wherefore this filtration cannot yield more fresh water than can be contained in the interstices of a column of sand of a certain length and proportionate to the saltness of the sea water. Howbeit, the removal of the salt from sea water, so as to obtain fresh water therefrom, is, practically speaking, an impossibility, except by evaporation."

In repeating this experiment I connected together several lengths of glass tubing of about two centimeters internal diameter, so as to make a tube similar to that figured by Normandy, in which the long arm of the J was 16 feet, and the shorter arm 6 feet in length, so that the column of sand with which the tube was filled was about 22 feet in length. The sand with which the tube was packed was fine, white Berkshire sand, the character of which will be described presently.

The liquid employed was a solution of common salt of about the same strength as ordinary sea water (29 grams to the liter). The sand was so fine and so closely packed that it took three hours for the liquid introduced at the top of the tube to appear at the orifice, and its passage was consequently so slow that the sand was thoroughly wetted, and the liquid could not run down between the glass and the sand ; it took, in fact, 45 minutes to collect an amount of 50 c. c. This first portion of the liquid which had passed through the column of sand was carefully analyzed, and was found to contain exactly the same proportion of salt as was contained in the original liquid. Although the sand employed in my experiment and the width of the tube may have differed from those used by Berzelius, it is certain that if the sand retained under any circumstances an appreciable quantity of the chloride of sodium, it would have been discovered in my repetition of the experiment. Other experiments of the same general character have led me to the same conclusion.

It is not difficult to explain in part, at least, how the popular idea arose. Way quotes Lord Bacon as speaking, in his "Sylva Sylvarum," of a method of obtaining fresh water, which was practiced on the coast of Barbary: "Digge a hole on the sea-shore somewhat above high-water mark and as deep as low-water mark, which, when the tide cometh, will be filled with water fresh and potable." Nowadays it is a familiar fact that in many localities it is possible to have wells of fresh water near the shore, the level of which varies with the tide, but we know that the freshness of the water is not due to the removal of saline matter from infiltrating salt water, and that the rise and fall is due to the indirect influence of the tide in offering more or less obstruction to the outflow of the ground water. The popular idea is, however, a difficult one to dislodge.

Lord Bacon also remembered "to have read that trial hath been made of salt water passed through earth through ten vessels, one within another, and yet it hath not lost its saltness as to become potable," but when "drayned through twenty vessels hath become fresh."

One explanation which may be offered to account for such an observa-

tion if, indeed, it was ever really made, and also for the results stated to have been obtained by Berzelius (and this will apply also to the experiment of Matteucci) is that the sand *was not perfectly dry.* If that were the case, as the saline solution passed through the column, the first portions which issued would be somewhat more dilute than those that followed subsequently. In order to illustrate this, I performed the following experiment. A quantity of sand, slightly moist, was packed in a cylinder 3 inches in diameter (in which it made a column of a foot in height), and a solution of chloride of sodium of about the same strength as that used in the previous experiment was poured upon the sand, and successive portions of the filltrate were collected and analyzed with the following results:

	Gram salt per cu. cent.		Gram salt per cu. cent.
Original solution contained........	0.02915	3d 10 c. c. filtered contained......	0.02374
1st 10 c. c. filtered "	0.01855	4th " " "	0.02477
2d " " "	0.02153	5th " " "	0.02563

I have somewhere read of a man who undertook to filter some vinegar through a barrel of sand, but found, after filtration had taken place, that, although he obtained a clear liquid, it was no longer vinegar. If the occurrence is authentic it may possibly be explained, partly by supposing that the sand was not perfectly dry, but most likely because the sand, like many natural sands, was not pure silica, but contained carbonate of lime in sufficient quantity to neutralize the small amount of free acid which vinegar contains. I doubt not that all similar statements admit of simple explanation, if all the facts in the case were known.

The sand used for the experiments recorded in this paper was fine, white Berkshire sand, No. 24, the greater part of which would pass readily through a sieve of 40 meshes to the inch, but be retained on a sieve of 60 meshes. The sand is nearly pure silica, but contains some particles of a black silicious mineral (tourmaline?). An analysis of a portion of the washed sand actually used in one of the experiments gave the following results:

	Per cent.
Matter soluble in water, largely organic matter...........	0.005
Matter soluble in hydrochloric acid, mainly oxide of iron and sulphate of lime.	0.025
Silica (SiO_2).......	98.990

The sand, before washing, contained a small quantity of some chloride (0.0114 per cent., reckoned as chloride of sodium), which it was not easy to remove completely, also a small amount of organic matter. For the experiments generally, the sand was first carefully picked over and then thoroughly washed and dried. For some of the experiments which follow, the sand was treated with hot nitric acid, then thoroughly washed and ignited.

In this place, I may put on record an experiment of filtering ordinary Cochituate water through sand. Four 2-gallon bottles, from which the bottoms had been cut, were arranged as represented in Fig. 2, and filled with sand. The bottles each held in the neighborhood of 10 kilograms of sand, and ordinary Cochituate water was allowed to flow slowly into the upper bottle of the series, and thence work its way slowly by gravity into the succeeding bottles. As the water stood only about two inches above the level of the sand in the first bottle, it took some time to traverse the entire series, which would be equivalent to a filter bed of somewhat

over 4 feet in depth. Five liters of water were thus filtered, and a partial analysis gave the following results:

PARTS IN 100,000 BY WEIGHT.

	Cochituate.	Filtered water.
Ammonia	0.0037	0.0062
"Albuminoid Ammonia"	0.0149	0.0142
Silica (SiO_2)	0.25	0.18
Lime (CaO)	0.71	0.73

I think that we can regard it now-a-days as agreed upon by all who have given any attention to the matter that if saline substances are removed to any extent by filters of pure or of impure sand, the action is only a temporary one, and that in the continuous use of a sand filter, it may be considered as amounting to nothing. This temporary removal may, however, if it is really a fact, be of considerable importance. Thus at the Dublin meeting of the British Association in 1878, Mr. Isaac Roberts asserted that certain wells in Liverpool had been constantly becoming more brackish, and this he ascribed to the fact that water was drawn from the (tidal) River Mersey into the sandstone, and that for a time a quantity of the saline matter was retained in the sandstone, but that the capacity of the stone was limited and was becoming exhausted.* To illustrate this matter experimentally he took two blocks of sandstone, each of which was 12 inches long and 12 inches wide and 13 inches high. A depression of one inch was cut in the top of each block to receive the saline solution, so that practically there were two blocks each of one cubic foot. He took water from the River Mersey (containing 1,334.9 grains of total chlorides to the gallon) and, after subsidence, a portion of the water was run in small quantities into the dished part of the first cube, until it began to drop from the bottom. When two fluid ounces had passed through, the quantity of chloride contained therein was determined, and it was found that 80.8 per cent. had been removed by filtration. The water was then allowed to filter through and drop into the second cube, and after it had passed through this second cube it was collected in portions and analyzed with the results given below.

	Quantity in fluid ounces.	Percentage of chlorides removed.		Quantity in fluid ounces.	Percentage of chlorides removed.
1st filtrate	3½	80.8	8th filtrate	8	44.68
2d "	4	76.6	9th "	8	31.9
3d "	4	71.27	10th "	8	25.53
4th "	4	64.89	11th "	8	21.27
5th "	4	57.44	12th "	8	10.63
6th "	4	53.19	13th "	8	10.63
7th "	4	46.8	14th "	18	8.51
				93½	

Although these statements are sufficiently explicit, my own previous experiments led me to doubt the explanation which was given, but at the time when the paper was read these experiments were not sufficiently advanced to justify me in stating publicly what I believed to be the true condition of things. My idea at that time was that the sandstone blocks used by Mr. Roberts could not have been thoroughly dry, although he thought that they were. They seem, from his statements, to have been used before they had been long from the quarry. It takes a

*According to De Rance (Water Supply of England and Wales), this increase in salinity is observed only in shallow wells near the docks, and not in the deep wells from which water is pumped for the supply of the city.

very long time to dry thoroughly a block of stone of that size, even if it is quite porous. My belief was that it was simply a question of what the druggists call percolation; that the salt solution placed on top of the block forced before it the water already contained in the pores of the stone and mixed with it but little. I believed that if the stone had been perfectly dry there would have been no effect observed, unless, as is the case with most sandstones, the rock actually contained some salt to start with, in which case the first portion of the liquid that came through would contain a trifle more salt than the subsequent portions. Mr. Roberts himself found that the chlorides intercepted by his cubes of sandstone were readily washed out by a subsequent treatment with spring water, which was allowed to percolate through. He obtained the following results after the stones had dried for some time:

	Quantity of filtrate in fluid ounces.	Percentage of the chlorides washed out.	
1st filtrate	24	157.77	101 fluid ounces.
2d "	45	122.22	
3d "	32	102.22	
4th "	40	55.55	92 fluid ounces.
5th "	40	4.44	
6th "	12	2.22	

I have since been able to confirm my view by actual experiment. In the first place, in order to repeat the experiment of Mr. Roberts, I procured two blocks of red sandstone from the Connecticut Valley, but found that the stone was so compact that water passed through it with great slowness. I consequently contented myself with using a single block, which was coated on the outside with asphalt varnish to lessen evaporation as much as possible. The stone was in my laboratory for about a year before I used it for the experiment, and was, consequently, thoroughly air-dried. A salt solution was used containing 30.33 grams of salt to the liter, and the first portions of the liquid which dropped through were collected and analyzed with the following results:

No. of portion.	Weight in grams of portion collected.	Weight of salt (in grams) in each *cubic centimeter.**
Original solution,	.....	0.03033
1.	25.33	0.06764
2.	5.02	0.04225

* To insure greater accuracy and to avoid evaporation the successive portions of the filtrate were collected in flasks and weighed. The volume was calculated from Schiff's tables of the density of salt solutions.

It will thus apppear, as actual experiment proved, that the stone contained, in its natural condition, a quantity of salt which was dissolved up by the first 30 c. c. or so of the saline solution, and that the water, after filtration, really contained more salt than before. No doubt, if further successive portions of the filtrate had been collected and examined, the solution would have eventually reached the original strength, perhaps, after 100 c. c. more had filtered through. At the time, however, I thought the stone contained too much salt for my purpose, and the experiment was not carried farther.

I afterward procured some samples of another variety of sandstone, namely, a light-colored, somewhat clayey and rather porous* stone from Ohio. The blocks employed were cut perpendicular to the bedding, and were protected by a coating of asphalt varnish, as before.

*A cube of the stone, measuring 4½ centimeters each way, absorbed 12 cubic centimeters of water, *i. e.*, about 13 per cent. of its bulk.

It seemed unnecessary to use blocks of as large size as those used by Mr. Roberts in order to establish the principle, and the blocks used measured 6″ × 6″ and 13 inches in height, with a depression of one inch cut in the top. The blocks were received in winter, and had been cut from a larger block, which had been exposed to the atmosphere for some time; they were, consequently, wet. One of the blocks (No. 1) was allowed to remain four days in the laboratory, until it appeared dry on the surface. The other (No. 2) was put in a warm place, and allowed to remain for four weeks, until there was reason to believe that it was thoroughly dried. The results of filtering a solution of salt through these blocks were as follows:

No. of portion.	Weight in grams of portion collected.	Weight of salt (in grams) in each *cubic centimeter*.
No. 1. Original solution	... ..	0.03053
1	11.72	0.00988
2	12.47	0.01971
3	19.63	0.02577
4	120	0.02873
No. 2. Original solution	......	0.03022
1	5.07	0.03643
2	11.26	0.03127
3	15.55	0.03055*

* This result is a trifle below the truth, as a drop or two of the solution was lost after weighing.

These results confirm exactly the ideas that have been expressed. In the case of the stone which was wet, the saline solution pushed before it the water, mingling with it to some extent; in the case of the dry stone, which contained a small amount of soluble chloride, the first portion of the filtered solution contained a trifle more salt than the original, which is just what we should expect.

In order that this explanation may appear beyond reasonable doubt, it may be worth while to give a record of a few more experiments.

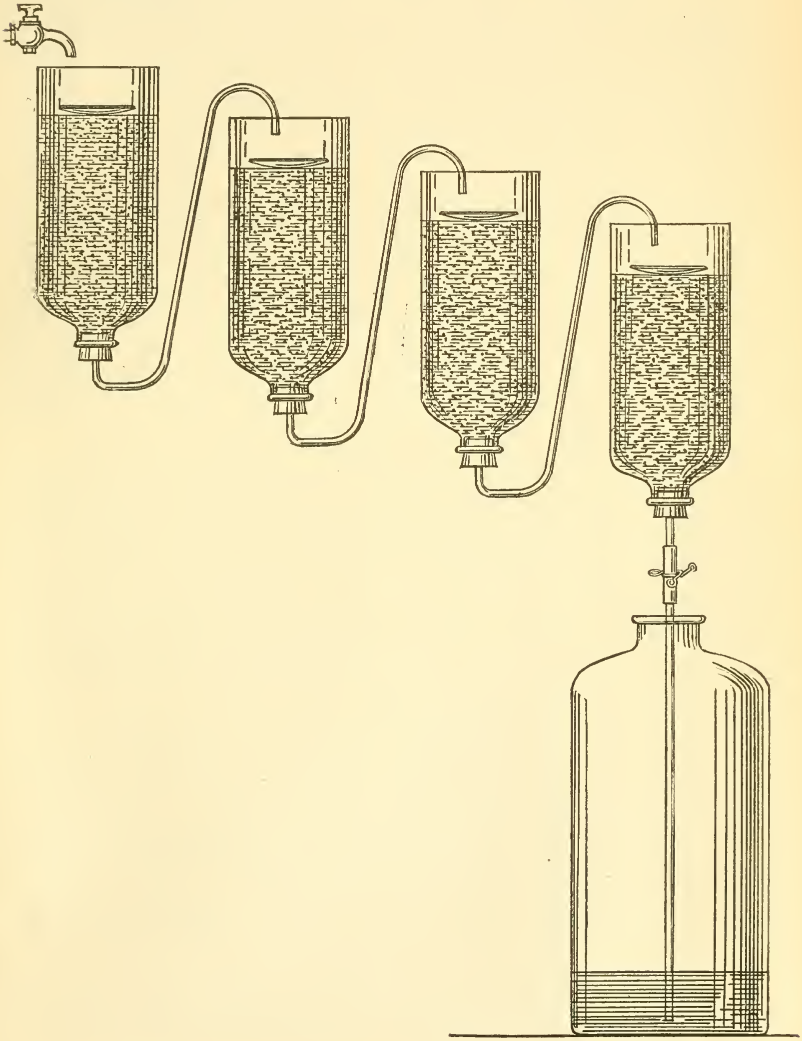
Some of the sand which had been washed carefully, but which was not entirely freed from chlorine, was thoroughly dried and packed in one of the inverted bottomless bottles shown in Fig. 2, forming a column of sand 13 inches high; a dilute solution of salt was then slowly poured upon the sand, so as to gradually displace the air, and the successive portions of the filtrate were examined with the following results:

100 c. c. of original solution contained	0.00154	gram chlorine.
The 1st 100 c. c. of filtrate "	0.01169	" "
The 2d " " " "	0.(0637	" "
The 3d " " " "	0.00525	" "
The 4th " " " "	0.00423	" "
The 5th " " " "	0.00332	" "
The 6th " " " "	0.00259	" "
The 7th " " " "	0.00209	" "
The 8th " " " "	0.00187	" "
The 9th " " " "	0.00167	" "
The 10th " " " "	0,00159	" "
The 11th " " " "	0.C0158	" "
The 12th " " " "	0.00157	" "
100 c. c. of the original solution "	0.00154	" "

In another experiment the arrangement was similar, and a certain solution of salt (call it *A*), containing 0.00539 gram chlorine in 100 c. c., was allowed to filter through until it came out of the same strength as it went in. The sand was allowed to drain for a time and then a more dilute solution (call it *B*), containing 0.00159 gram chlorine in 100 c. c., was poured upon it; successive portions of the filtrate were then ana-

lyzed, and from the result it is easy to see how the new salt gradually displaced the old. (I may note that the interstices of the sand would hold about 3500 c. c. of water, as determined by experiment.)

100 c.c. of solution A	contained 0.00539	gram	chlorine.
The 27th 100 c.c. of filtrate	" 0.00543	"	"
The 28th " " "	" 0.00541	"	"
After adding solution B :			
The 1st 100 c.c. of filtrate	" 0.00531	"	"
The 3d " " "	" 0.00534	"	"
The 15th " " "	" 0.00509	"	"
The 20th " " "	" 0.00323	"	"
The 25th " " "	" 0.00188	"	"
The 30th " " "	" 0.00161	"	"
The 35th " " "	" 0.00159	"	"
100 c.c. of solution B	" 0.00159	"	"



In all questions like that now under discussion, there are two points to be considered. In the first place, whether a certain statement is, for practical purposes, true; and secondly, whether, if it be not true from a practical point of view, it may still be true to a limited extent, from a scientific point of view. Thus, for instance, we might pronounce a certain article free from arsenic, meaning that for all practical purposes the said article could be considered as free from the dangerous element; but still, in a substance which was practically free from arsenic, it might be possible, by careful chemical experiment, or by working with very large quantities of the material, to show the presence of a minute trace of the substance in question. We believe that for all practical purposes it may be asserted without hesitation that the action of sand on saline solutions is nothing, unless some chemical action can take place under the given circumstances; we will now proceed to inquire whether, from a strictly scientific point of view, it may not be true that a minute amount of the dissolved saline matter is attracted to and retained by particles of sand

Professor Way, in a paper already quoted, referring to this matter, says:

"It is to be observed that this property of sand to arrest and separate saline substances from solution, is very limited in extent, and requires careful arrangements to make it evident at all by experiment. * * * The property is the result of two opposite forces, that of the surface attraction of the sand, and that of the water for the salt. It can only, therefore, operate a condensation of the salt in relation to the strength of the solution, the salt being continually shared in given proportions between the sand and the water, so that eventually the whole is washed away."

Professor Johnson, in his "How Crops Grow," says:

"Cohesion prevails in solids, and opposes freedom of motion among the particles. In liquids cohesion is not altogether overcome, but is greatly weakened, and the particles move easily upon each other. When a lump of salt is put into water, the cohesion that otherwise maintains its particles in the solid state is overcome by the attraction of adhesion which is mutually exerted between them and the particles of water, and the salt dissolves. If, now, into the solution of salt any insoluble solid be placed which the liquid can wet (adhere to), its particles will exert adhesive attraction for the particles of salt, and the tendency of the latter will be to concentrate somewhat upon the surface of tbe solid.

"If the solid, thus introduced into a solution, be exceedingly porous, or otherwise present a great amount of surface, as in the case of sand or humus, this tendency is proportionally heightened, and a separation of the dissolved substance may become plainly evident on examination. When, on the other hand, the solid surface is relatively small, no weakening of the solution may be perceptible by ordinary means. Doubtless the glass of a bottle containing brine concentrates the latter where the two are in contact, though the effect may be difficult to demonstrate."

In order to throw light upon this matter, I have for some time been at work upon an investigation, the full details of which will be published when the investigation is completed. I will simply indicate at this time

some of the experiments which have been performed, and first in a line indicated by Mulder*. Mulder's experiments were as follows:

20 c. c. each of solutions of sulphate of potassium and sulphate of sodium were left for an hour in contact with 10 grams of sand which had been boiled with hydrochloric acid and water, and then ignited. The solutions were then filtered through dry filters and the sulphuric acid determined in aliquot portions by means of chloride of barium. He found :

	Original solution.	After treatment with sand.	Difference.
Sulphate of potash	0.531	0.526	0.005
Sulphate of soda	0.437	0.434	0.003

In a similar manner solutions of chloride of calcium and chloride of sodium were treated with sand and the chlorine determined as chloride of silver.

	Original solution.	After treatment with sand.	Difference.
Chloride of potassium	0.691	0.680	0.011
Chloride of sodium	0.713	0.700	0.013

Mulder considers these small differences as showing a slight, but appreciable, retention of the salt by sand, but it is certain that the differences in the cases of the sulphates are altogether too small for any such conclusion, when we consider that the sulphate was determined as sulphate of barium. My own experiments, arranged in tabular form, are as follows:

Substance.	Weight of sand.	Volume of salt solution.	Time of contact.	Strength of original solution per cubic centimeter.	Strength of solution after treatment per cubic centimeter.
Chloride of sodium	20 grms.	50 c. c.	1 hour.	0.003472 grm.	0.003465 grm.
" "	20 "	50 "	17 hours.	0.003472 "	0.003466 "
" "	25 "	25 "	....	0.002970 "	0.002960 "
" " *1	25 "	50 "	2 hours.	0.001473 "	0.001473 "
" of calcium*2	25 "	50 "	1 hour.	0.001377 "	0.001375 "

*1 Mean of 6 closely agreeing determinations.
*2 Mean of 4 closely agreeing determinations.

The experiments, which were conducted in essentially the same way as those of Mulder (except that the chlorine was determined by the ordinary volumetric method), fail to show any action of the sand, the differences being well within the possible experimental error.

My note-books contain the records of a great many experiments on filtering dilute saline solutions through sand, in which I used one of the bottles shown in Fig. 2, the solution being passed but slowly through this comparatively large amount of sand. A few examples will suffice for the present purpose.

First, I will mention an experiment with chloride of sodium, in which a very dilute solution was employed, and a large amount of time was

*Die Chemie der Ackerkrume (Deutsch von Müller), I., p. 457.

spent in the previous treatment of the sand, in order to have it as free as possible from chlorine. The results obtained were as follows:

100 c. c. of the original solution contained	0.0017	gram	salt.
The 1st 100 c. c. filtered "	0.0026	"	"
2d " " "	0.0024	"	"
5th " " "	0.0021	"	"
10th " " "	0.0018	"	"
15th " " "	0.0017	"	"
20th " " "	0.0017	"	"
30th " " "	0.0017	"	"
40th " " "	0.0017	"	"

In this case I believe the somewhat larger amount of salt found in the first portion of the filtrate was due to the fact that a small amount of chlorine remained in the sand, and was carried out by the first portions of the liquid. It will be noticed that the absolute amount of chlorine in excess is very small, although, with so dilute a solution, the relative amount seems large. Another possible explanation of the observation has suggested itself to me, and to this I will refer later.

The next experiment mentioned will be one in which a dilute solution of quadroxalate of potash was employed, the amount being determined by means of a solution of permanganate of potash. There was great difficulty in working with dilute solutions of oxalic acid, or of the oxalates, on account of the change which such dilute solutions undergo spontaneously. The following results are tolerably satisfactory:

100 c. c. of the original solution destroyed	5.17	c. c. of the permanganate.*
The 1st 100 c. c. of the filtrate "	5.51	" " "
The 2d " " " " "	5.33	" " "
The 3d " " " " "	5.38	" " "
The 5th " " " " "	5.27	" " "
The 7th " " " " "	5.31	" " "
The 10th " " " " "	5.23	" " "
The 20th " " " " "	5.16	" " "
The 30th " " " " "	5.21	" " "
The 40th " " " " "	5.21	" " "

* The solution was about $\frac{1}{100}$ normal.

A possible explanation of the apparently larger amount of oxalic acid in the first portions, which, however, is a very small absolute amount, is that a little organic matter may have been taken up by the solution, from the sand, and if so, it would act like the oxalic acid toward the permanganate solution. Another possible explanation will be referred to presently.

Another experiment in this same line was with a solution of sulphate of copper. This salt was chosen because the copper is easily determined, and because there was likely to be nothing in the sand which would naturally tend to increase or decrease the amount of copper.

Expt. No. 1:

50 c. c. of original solution contained	0.2984	gram copper
50 c. c. " " "	0.2978	" "
Mean	0.2981	" "
The 1st 50 c. c. of filtrate contained	0.2962	" "
The 2d 50 c. c. " " "	0.2974	" "

Expt. No. 2:

50 c. c. of original solution contained	0.3130	" "
50 c. c. " " " "	0.3142	" "
Mean	0.3136	" "
The 1st 50 c. c. of filtrate contained	0.3123	" "

In both of the cases the copper appears to be lower in the filtered liquid than in the original, but the difference is so near the possible analytical

error that it is hardly safe to base an assertion on it. I hope to make further experiments in this same direction.

To turn now to another line of experiment. Every one has noticed that when a strongly colored solution, such as sulphate of copper or bichromate of potassium is let fall upon a piece of filter paper, the strongly colored central portion of the drop is surrounded by a colorless annulus where the paper seems to be simply wet with water. A number of years ago, Schönbein experimented with a considerable number of saline and other solutions, into which he dipped strips of filter paper, and observed the height to which the solution rose by capillarity. He found in many cases that the water of the solution was drawn to a greater height than the substances dissolved, so that there was an evident separation of the dissolved salt.

Working in this general direction, I made various attempts to devise experiments which should throw light upon the question in hand. A number of experiments were made by packing dry sand in glass tubes, and immersing one end of the tube in a saline solution. When the liquid had risen as far as it would by capillarity, the tube was divided into sections, and the various sections analyzed to see whether the solution in one part was of the same strength as in another. The results thus far obtained are somewhat irregular, and, as the investigation is not finished, I prefer not to publish them, or the results of other experiments of capillarity, at the present time. I will only say that I am inclined to think that they will show a slight separation of the salt from the liquid. If this prove to be so, we may have another explanation for the results observed in the case of the dilute solutions of salt and of quadroxalate of potash alluded to above. It is possible that when a solution passes through a mass of sand, or of sand stone, as in some previous experiments, it finds its way somewhat irregularly, and there may be portions of the mass which do not become thoroughly wet, and from which the air is not wholly expelled. Into these cavities, if they may be so called, some evaporation may take place, and the solution may be drawn by capillarity, so that the first portions which issue from the filter may be somewhat more highly charged with saline matter than subsequently. I doubt very much whether this is so; in the case of a very compact stone the progress of the liquid through the stone may be due to the action of capillarity as much as to hydrostatic pressure; and if such a separation as has been indicated is possible, we should expect that the first portions would contain somewhat less of the saline matter than subsequent portions. The experiments already recorded seem to show that such a separation cannot take place, to any considerable extent; but I hope to make a series of experiments in a line upon which I have begun, using rods of natural sand stone absolutely free from chlorine, if I can succeed in obtaining such stone.

Perhaps I should apologize for the length of this paper. Experiments on this subject have occupied the spare time of myself and my assistants, at intervals, for the last six or seven years, and it seemed to me well to put a portion of them, at least, upon record. In so doing I take occasion to acknowledge my indebtedness, especially to Mr. Thos. F. Stimpson and Mr. F. P. Hall, who have assisted me in the past, and to my present assistant, Mr. David Wesson.

DISCUSSION ON TRACK PROBLEMS.

By A. W. Wright, Member of the Western Society of Engineers.
[Read April 1, 1884.]

Your Committee on Transportation, Railroads, etc., etc., would call your attention to the letter from our fellow member, Samuel McElroy, on "Track Problems" in *Railroad Gazette*, March 28, 1884. You will notice that Mr. McElroy says, in speaking of street railroads, "that a play of ⅞ to 1¼ inches is allowed on curves of 60 to 75 feet radius. This is not the *usual* custom. More than 100 street car companies use grooved rails for their curves and lay them to *tight* gauge. This list embraces some of the largest companies in the United States, and curves of 28 feet radius are passed without difficulty, but the wheel base is usually 6 feet instead of 8 feet as supposed by Mr. McElroy.

A few companies prefer one grooved rail for inside of curve and one flat rail for outside, upon which the wheel travels upon its flange.

The length in gauge lines of a curve with centre radius of 45 feet turning an ∟ of 90°, a very common practice, is as follows. Length of circular arc = radius × 1.5708 :

Length on outer gauge line (all in inches)......	568¼ × 1.5708 = 892.6071
" " inner " " "	511¾ × 1.5708 = 803.8569
Difference in length......................	88.7502

Therefore, when both wheels are rigid upon one axle the one wheel must slide 7 feet 4¾ inches. Some street railroads, to lessen this resistance, as above stated, have the outside wheel travel around the curve upon its flange. The ordinary street-car wheel has a diameter of 30 inches, with flange ½ inch deep. Suppose the inside wheel revolves on its tread, having a diameter of 30 inches, its circumference = 30″ × 3.1416 = 94.248″.

In the above distance $\frac{803.8569''}{94.248} = 8.5+$ revolutions.

The wheel traveling upon its flange with diameter of 31 inches × 3.1416 = 97.3896 inches circumference. In 8.5 revolutions it travels, supposing there to be no slipping, 827.8116 inches. The length on outer gauge being 892.6071, deducting 827.8116 leaves 44.8955 inches, or about one-half the distance it has to slide when traveling upon its tread; but this advantage is considered by the majority of street railroad men as more than equaled by the fact that the flange being comparatively sharp, soon wears grooves into the flat rail upon which it travels. I have experienced no difficulty from a curve with centre radius of 32 feet 6 inches laid to tight gauge with grooved rails.

Mr. Charles E. Emery, C. E., reports the extra resistance of curve with 40 feet radius at 41.77 pounds per ton. I have made numerous dynamometer experiments upon curve resistance with horses and with men, but the fluctuations were so great the tests were unsatisfactory. So near as I could estimate the increased resistance on curve of 45 feet radius grooved rails = 66 pounds per ton.

D. K. Clarke, "Tramways," Vol. II., page 179, estimates the resistance of 22-foot radius curve as double that of a straight line.

In estimating the curve resistance upon horse railroads many things

must be taken into consideration, whether or not the groove is clean, the car wheels exact gauge; where the horses walk, whether in the horse path or astride of the outside rail. I find that filling the groove with water reduces the friction more than oil, for the latter holds the dirt.

In conclusion, the question raised by Mr. McElroy is full of interest, and your Committee would be pleased to hear from our members upon the subject, and submit the question to you for discussion. I never narrowed gauge on steam railroads at bridges or crossings.

LOCATION OF THE NORTHERN PACIFIC RAILROAD ACROSS THE ROCKY MOUNTAINS.

By J. C. Chesbrough, Member of the Western Society of Engineers.

[Read April 15, 1884.]

The most difficult problem to solve by the engineers of the Northern Pacific Railroad was "the proper place for crossing the Rocky Mountains." No other question of location was so far-reaching. After many examinations by different engineers and explorers, from the time of George Stevens in 185— to 1881, the question was reduced to a choice between the "Pipe Stone" and "Mullan" passes. The decision was made in favor of the latter—not the actual Mullan Road Pass, but a lower one, a little to the left of it, going west. It was over 500 feet lower than the Pipe Stone, beside affording a better opportunity for reduction by tunneling. As the Pipe Stone route did not possess sufficient compensating advantages the Mullan was wisely chosen as the preferable one.

It may be interesting to know that the top of grade at Mullan Pass is not the highest point of the Northern Pacific Railroad. The top of grade at the "Belt Range," 125 miles east, is a few feet higher. The Belt Range is a spur of the Rocky Mountains, and divides the waters of the upper Yellowstone and Missouri rivers.

The writer was employed by the division engineer, Col. J. T. Dodge, to make the final location, and his duties commenced near the "Spokane Pass," about 15 miles east of Helena. This pass is one of the many remarkable topographical features of the line, affording a direct route to Helena, with moderate grades and cost.

There was nothing of note in an engineering point of view, until reaching the "7 Mile House" west of Helena. To the tourist, however, this portion of the route will always be one of great attraction.

The crossing of the lower Greenhorn, at 7 Mile House, was the point of "foot of grade" on all the trial lines projected for reaching the summit of the Rocky Mountains at Mullan Pass. This point was where the converged branches of the Greenhorn entered the Helena Basin. It was also considered as unavoidable that the line from the summit should follow the hills on one side of the main watercourse, being carried in a very short distance hundreds of feet above its bed, which in a distance of 3 miles from the eastern end of Mullan Tunnel falls 700 feet. The hills to the left were chosen as affording the only practicable way of "devel-

oping" distance, and finding holding ground for the assumed maximum grade of 2.2 per 100, or an average of a little more than 2 per 100 after compensating for curves. Thus having decided the question of top of grade with the involved length of tunnel, the work in hand was to find a path to get down about 1,400 feet. After crossing many yawning ravines, and turning the intervening spurs, or crossing the "divides" between the principal watercourses—and a little more than half way down the grade, a fearful looking gulf was to be crossed. "Skelly's Gulch" was over 200 feet deep at grade line, and ¼ mile wide. Several lines were run across, and the last or "short line," a very bold one, 245 feet above the brook bed, was near being adopted. It may not be out of place here to say that the cost of the farce of "driving the last spike" would have been better used in building a steel structure across Skelly's Gulch, the dread of which caused the line to be turned away.

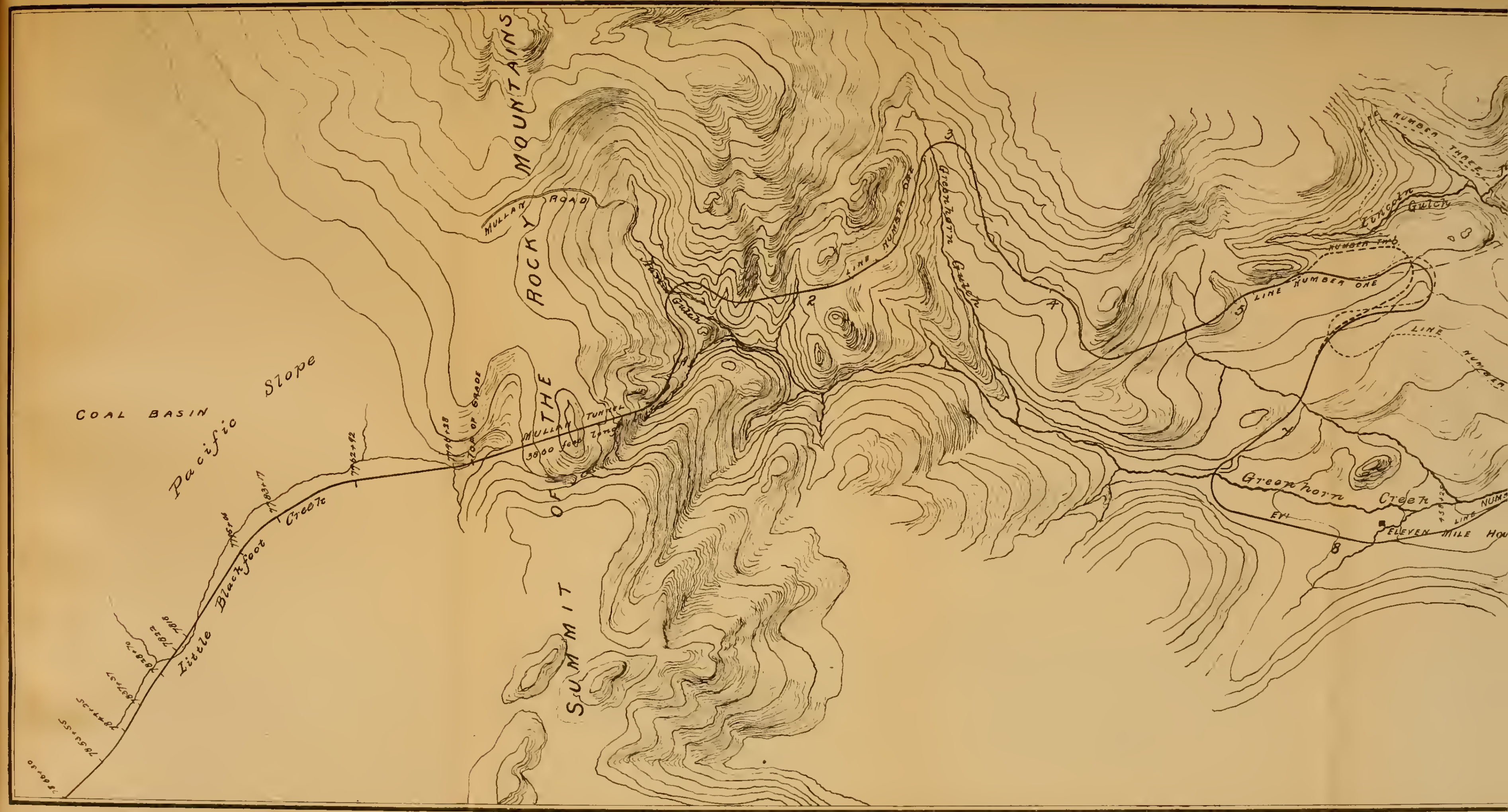
At the last moment orders came from headquarters to find, if possible, some way of avoiding the high crossing, even at the expense of a considerably lengthened line and shorter curves. A satisfactory line was found, and that discovery has led to writing this article.

The first suggestion was to try a meandering line, following up the Western side of Skelly's to get a lower crossing, and then, curving short to the right, follow down the eastern side. This plan, to avoid greatly increased length, would necessarily keep the line down in the gulch, and thus regain the lost advantage in distance by cutting off the détours toward the lower end of the steep grade on the other lines. The result was a very crooked line with many short curves, along the sides of high and steep hills on a great portion of the distance. It was in every way an objectionable plan. Giving this up as a bad job the Assistant Engineer set his wits at work to invent some other scheme. The idea which led to success came like a flash. It was simply like this. Wheel right-about on the west side of the spur, which forms the west side of Skelly's Gulch, and by "looping" the line down the slope of the main valley get to as low a point as required.

A double loop was traced, but, except proving the practicability of the scheme, and its superiority, as compared with the first suggestion, it was not satisfactory.

The next, and successful trial, was to extend the lower side of the first loop, and running westward, get to the bottom of the valley in that direction. The return was made at the mouth of the Greenhorn Cañon, at the point referred to in this article as being only three miles from the Mullan Tunnel, and 700 feet below it. The line had now lengthened out to seven miles, and crossed the valley at an elevation of only 40 feet! From that point to foot of grade, and on to Helena, the grade line was at no place 40 feet above the lowest ground. The curves were easy (4° the shortest) and no heavy work. The only objections to the line were an increase of ⅔ miles in distance, and the necessity of a circle of maximum curvature in making the two loops.

The saving in expense of first cost of line was at least a quarter of a million of dollars. Considering the great cost of work, so far from the base of supplies, this line was a fortunate discovery. It also shows the importance of a thorough topographical survey before deciding upon



ROCKY MOUNTAINS
SUMMIT OF THE
MULLAN ROAD
MULLAN TUNNEL
3860 feet long
COAL BASIN
Pacific Slope
Little Blackfoot Creek
Greenhorn Gulch
Greenhorn Creek
Lincoln Gulch
LINE NUMBER ONE
LINE NUMBER TWO
LINE NUMBER THREE
ELEVEN MILE HO


PLAT OF THE
CROSSING OF THE ROCKY MOUNTAINS
ON THE
NORTHERN PACIFIC RAILROAD.
High Hills
LINE NUMBER ONE
LINE NUMBER THREE
LINE NUMBER FOUR
LINE NUMBER FIVE
ROAD TO FORT BENTON
MULLAN ROAD
Jeff Davis Gulch
Skelly's Gulch
St. Louis Gulch
Creek
ELEVEN MILE HOUSE
SEVEN MILE HOUSE
TO HELENA
Magnetic Meridian
N
S
9
10
11
12
13
14
7037+63
7020+83
Scale of Feet.
0 250 500 750 2000 4000 6000 feet.
Main contour lines 50 feet apart.

the plan of crossing a great mountain. In this case a way was discovered for doing what had hitherto been considered impossible. Skelly's Gulch was completely flanked.

To illustrate the subject a sketch has been prepared. No. 1 is the original located new line. No. 2 is a modification of it subsequently made by the division engineer. No. 3 is the meander line. No. 4 the first loop line idea, and No. 5 the "Short" line, across Skelly's. which came near being adopted.

The first kept on the southern side of "Iron Ridge" and in deep cutting, with heavy embankment on the return, and to get back to holding ground it was necessary to extend beyond the semi-circle. The division engineers preferred tunneling through the ridge and wheeling back on higher ground to the heavy embankment. There was a low depression at the eastern part of the ridge which made the tunnel scheme practicable. It shortened the line a little and reduced the amount of curvature considerably.

The writer, however, did not have anything to do with this modification, or with the construction of the work on that part of the line, and is not posted as to the full effects of the change. In conclusion, the writer hopes to be pardoned the egotism of saying his plan of getting down the Atlantic slope of the Rocky Mountains is a unique affair. It was not an unavoidable "horseshoe" nor a "spiral" readily suggesting itself. It was the successful reading of an intricate page of topography.

After crossing the mountain the location of the line down the Pacific Slope was a simple affair.

The duties of the writer, as locating engineer, extended to the mouth of the Little Blackfoot, 35 miles from "Mullan."

THE NATIONAL ELECTRIC SIGNAL SYSTEM.

By Isham Randolph, Member of the Western Society of Engineers.

[Read April 15, 1884.]

The paper which I have the honor of presenting for your consideration is upon a subject deeply important to, and full of interest for, the railroad engineer, no less than the electrician, namely, an electric signal which owes its existence to the inventive genius of an engineer named Le Grand, and the patient expenditure of thought, time, and money, by the men who have undertaken to develop his novel plans. Let me say, however, at the outset, that I do not undertake to handle my topic technically or scientifically, for I am nothing of an electrician and have ever regarded this subtle element with that feeling of reverence, akin to awe, which mysterious manifestations of power always inspire in the beholder. I can only tell you in the plain speech of a layman what I have seen and the understanding which I have of it as explained to me by the gentlemen at the head of this enterprise. The question of a suitable system of signals for our network of tracks about this steel-environed city has given the officials of our Company much anxiety, and our needs have caused us to expend time and money on experiment and investigation.

At one time we hoped we had found just what we needed, in an electric signal dependent for its operation upon a track circuit, in conjunction with clock-work; but this proved an utter disappointment to us and was abandoned. Some months since Col. Meek, of the National Electric Signal Co., was introduced to us by an official of the Louisville, New Albany & Chicago R. R. Co., and the system now being considered was brought to our notice by him. He made claims for his devices which, in the light of our past experience, seemed preposterous, but being vouched for by the gentleman who introduced him, a cool, clear-headed man—himself an electrician—his claims could not be scouted without investigation. The most incredible of his statements was, that in his system it was unnecessary to insulate the wires, as they could be carried without protection through earth or water, and an electric circuit be maintained with certainty.

Our people decided to investigate the system, and I was sent to Louisville, Ky., to inspect its workings on the Short Line Railway. The day of my arrival upon the scene of my investigations was stormy, and I prosecuted them in a pouring rain. What I saw I shall tell you.

The signals were working just as they had been represented. As soon as either locomotive or car came upon the block, the signals made a quarter revolution, stopping with the danger sign disclosed; at the same instant the gongs began to sound and this continued as long as the track was occupied, but when the last wheel left the block there was silence, and the danger signal was reversed. When a switch was set for the side track the warning sound of the gong called attention to the fact, and all the signals went to danger and so remained until the switch was restored to the main line. If, however, a car was left on the siding, too near to the frog to admit of safe passage on the main line, gong and signal proclaimed the fact, and nothing but the removal of the car would change the signal or quiet the gong. These were the visible effects wrought out by the new discovery. The circuit is a metallic one. The battery is what is known as a quantity battery, the cells of which are exactly similar to those in the "Callaud battery" commonly used for telegraphic work, but the peculiarity of it is—and there lies the secret of the whole system under consideration—that instead of connecting copper to zinc, as is done in the common battery, the zincs are all connected together, and the coppers likewise, copper to copper; the circuit is made by connecting a wire from the zincs to one rail, and a wire from the coppers to the other rail. The joint connections for insuring an unbroken circuit are made by means of broad flat springs, in shape like the bow which was always carried by Cupid when in a shameless way he stood for a portrait; the ends of these bows press against the rail on either side of the joint underneath the base of the rail, and they are kept in place by clamps at the centre which are slipped on over the flanges of the angle bars (see drawings). The length of the block varies, of course, to meet any required conditions. At the end of the block furthest from the battery a wire is attached to one of the rails, and is then carried on poles along the full length of the block and back again to a connection with the other rail; as soon as this is done the circuit is completed. Now, having established the circuit, the signals are placed along it wher-

ever needed, and relays are cut in for operating them. The disks which seem best adapted to railroad uses are of red glass, 23 inches in diameter, revolved upon a vertical axis, to which an armature is attached, to be acted upon by the magnet of the relay. This armature is acted upon by the relay of the metallic circuit just described, and also by the magnet of a battery local to each signal. The battery for working the block is more powerful than the local battery, the latter having but two cells, while the former has from eight to ten. The disk is so held by the magnet on the block circuit that its surface is parallel to the track, and is, therefore, practically invisible in that direction. The instant the block is entered upon by a pair of wheels a new and shorter circuit is formed through wheels and axle, and the current is thus diverted from the wires on the poles, which, of course, demagnetizes the relays on the circuit; the local battery comes into instant play, causing the disk to make a quarter revolution, which presents its surface to the line of vision along the track. Wherever on the block a switch is encountered, the circuit is kept up by wires carried under ground, and connected with the rail on either side of the frog, and the break occasioned by the throw rail is overcome in like manner. Whenever, as at the end of a block or the clearing point on a siding, insulation is required, it is accomplished by using the old Trimble wood joint, dispensing with the iron fish plate which was used on the inner, or gauge, side of the rail. To guard against the possibility of the ends of the rails being brought together by expansion, heavy cast-iron lugs are made fast to the sides of the rails at each end of the wooden splice, which effectually keeps the rails apart until these lugs are broken or the wood crushed, neither of which is likely to occur. As before stated, side tracks are insulated at a safe clearing distance from the frog, and the rails between this point and the main track are by means of underground wires connected with the rails of the main track, or in other words put in the same circuit, so that as long as a pair of wheels stands upon this space the signals are affected just as they would be by the occupation of the main track. Each signal post at a switch is provided with a vibratory gong which is operated by the local battery whenever the block circuit is broken. On the switch stand is a small electric switch which is arranged to break the block circuit whenever the switch is thrown for the siding and to restore it again as soon as the switch is right for the main line. This, gentlemen, gives you as clear a statement of the working of the National Electric Signal as my comprehension of it enables me to present. I tried to get an explanation of the fact that the circuit from a quantity battery can be maintained without insulation although the wires may be exposed to water or carried underground, and as nearly as I can get at it, it lies in the fact that the current from a quantity battery is absolutely without tension, although ample in volume (and the volume may be increased indefinitely without imparting the quality of tension), and the further fact that every conductor of electricity has in it an element of resistance, which resistance must be overcome by the inherent tension of the current which it conveys. Hence the new tension circuit cannot transfer itself from one conductor to another, but must remain in the conductor originally charged by the battery. If

there are among us any who have given particular attention to the study of electricity, I commend this question to their careful investigation and shall feel greatly obliged for any light upon it which will make my comprehension of it clearer, and I doubt not that my interest in it is shared by our membership generally.

COMPARATIVE ECONOMY OF COMBINED AND SEPARATE SEWERS.

By Robert E. McMath, Member of the Engineers' Club of St. Louis, and Am. Soc. C. E.

[Read May 8, 1884.]

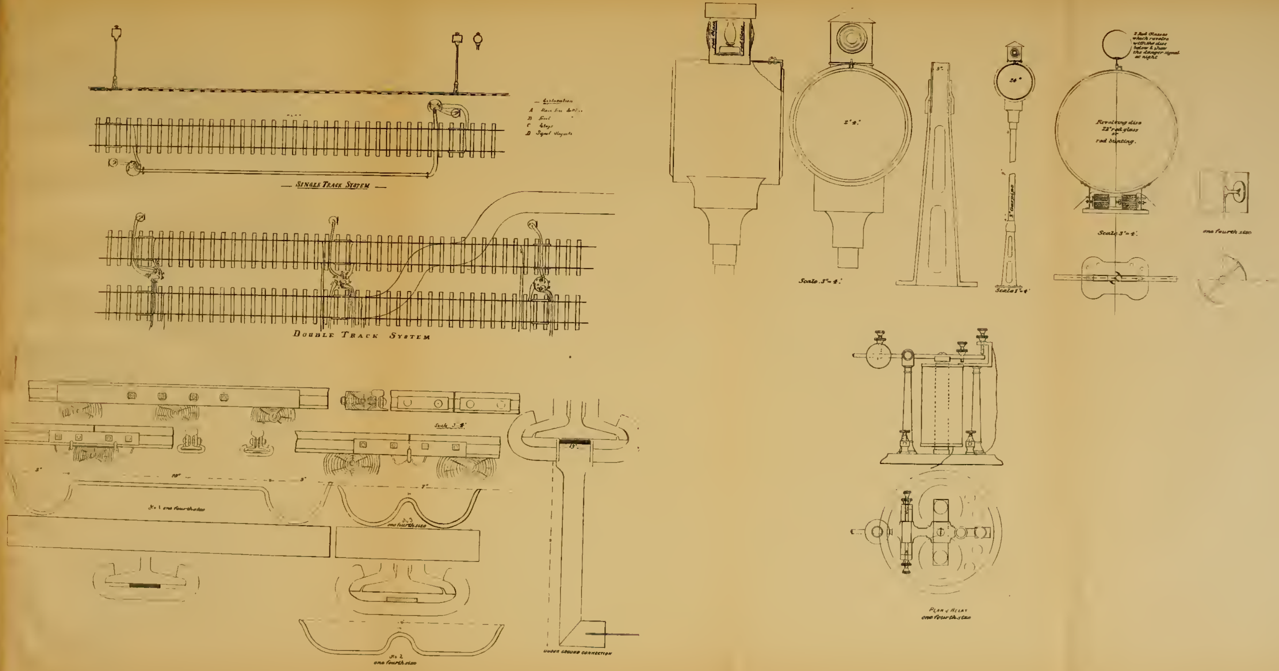
In Mr. Chanute's reply to Mr. Moore's paper (printed in March-April number of the Journal), the cost of the St. Louis system of sewers is stated at $30,146 per mile, and contrasted with the cost of the Memphis system, stated at $6,875 per mile. In the same paragraph the cost of cleaning Memphis sewers, $70 per mile, is contrasted with Brooklyn $133. and Providence $282. St. Louis ought to have appeared in the second comparison. The cost of cleaning has averaged $23.71 per mile for 7 years, 1878–1884, ordinary repairs $20.39, together $44.10. Chicago sewers in 1883 cost $14.78 for ordinary repairs, and $89.02 for cleaning, together $103.80 per mile.

Since questions of cost have an important bearing upon the practical decision or choice between the combined and separate systems in any specific case, it is essential that such comparisons should be fair and on equal terms. If St. Louis is to be used as an example of the cost of a combined system, then an estimated cost of sewering St. Louis by the separate system should be the other side of the comparison. Also, since the estimate for the separate system would be based on present prices, methods of work, and material, the contrasted figures of actual cost should in fairness be cleared of the effect of war inflation prices, and of obsolete ideas, methods, and materials. In other words present practice under both systems should be compared, and not the combination of accidents represented by the aggregate cost given in reports.

Clear the cost of St. Louis sewers of items irrelative to the discussion, and the combined system will not suffer if St. Louis be taken as a representative.

The total cost of sewers, including maintenance and miscellaneous expenses for over 30 years, is stated in the report for the year ending April, 1883, at $6,571,733.39, mileage, 218.31; from these figures Mr. Chanute would have got $30,103 per mile. But the same report says the aggregate for maintenance and expenses was $784,868.22. Making this reduction, the construction cost is found to be $26,508 per mile.

St. Louis sewers should be classed as trunk, main, branch and lateral. Of the four trunk sewers, Ferry reaches about 3 per cent. of its ultimate drainage, Rocky Branch and Mill Creek each 28 per cent. and Southern sewer 1.4 per cent. Consequently the accounts show a large part of the ultimate cost of a sewer system, but only a small fraction of the ultimate mileage, hence an excessive present average cost per mile which misrepresents the real expense of the contemplated system. The largest of these



SINGLE TRACK SYSTEM
DOUBLE TRACK SYSTEM
Scale 3" = 4'
No 3 one fourth size
No 2 one fourth size
UNDER GROUND CONNECTION
2' 4"
Scale 3" = 4'
24"
Scale 3" = 4'
2 Red Glasses which revolve with the disc below & show the danger signal at night
Revolving disc 22" red glass or red bunting.
Scale 3" = 4'
one fourth size
Plan of Relay one fourth size

trunk sewers has cost nearly $75 per running foot, the smallest nearly $18. Mean of the four, $241,296.00 per mile. Obviously it would not be fair to compare St. Louis with a smaller city, or one whose topography did not necessitate such large trunks, as contrasted cases of the combined system, let alone a comparison of systems. The trunk and main sewers, as now built and planned, would be necessary for St. Louis whether the combined or separate system were adopted for detail drainage, because the length and discharge of the water courses is too great to be treated in any other way in a large city. The St. Louis branch and lateral sewers by themselves constitute the system which should be compared in discussing the subject. These embrace (April, 1884) 174.92 miles, and have cost $2,932,588.34, or $16,765 per mile. But this cost includes much work done when it was thought that all sewers should be large enough for a man to enter, hence brick sewers were built where pipes would now be used. Moreover, a great deal was done at inflation or war prices, 1862–1873. From 1873 to 1883 the mean cost was $12,808 per mile. The substitution of pipe sewers to the full extent possible under the combined system dates from 1877; therefore the work done from 1877 to 1884 is what should be taken as representing present practice. The average cost per mile during these years has been $10,271, and some of these were laid in rock excavation: the cost includes inlets, manholes and junctions. Taking St. Louis prices, I estimate the average cost of separate sewers for house drainage alone, with junctions and manholes, at $6,080 per mile, or $59\frac{2}{10}$ per cent. of the present cost of the combined system. For the same territory an equal mileage would be required, hence cost per unit of area will be in the same proportion as per unit of length. The mean cost per square of 100 square feet since 1877 has been $\$1.28^4$. The proportion $59\frac{2}{10}$ per cent. would give for a separate system 0.76 per square. For an ordinary sized city lot, say 25 by 130 feet, the sewer tax at above rates would be $41.73, and $24.70 respectively. The real question at issue is which system is best worth its cost to the lot-owner. The money difference, $16.97, is an insignificant fraction of the cost of a residence or business house.

Connecting the house with the sewer will cost practically the same under either system; but the separate will leave the owner with storm water from roof and lot surface undisposed of. By the comparison above he has a balance of $17.00 as compensation for the inconvenience, or as a fund with which to lay storm water drains. Ordinarily the drains required to carry the water to the street gutter will consume this balance. Hence for city conditions the claim of economy made for the separate system is unwarranted. If the average lot front was 50 feet there would be a small advantage in favor of the separate system; this advantage would increase with the dimensions of lot. That is, under the conditions of a large business town and dense population, the combined system is the cheapest, as well as better adapted to the requirements. The separate system, on the other hand, is well adapted to villages and city suburbs, where economy in mileage cost is a necessity, and where surface waters are comparatively uncontaminated by traffic and greatly diminished in quantity by the absorbent surface of lawns and cultivated plots.

THE WIND-MILL OF TO-DAY AND ITS USES.

By James W. Hill, Member of the Engineer's Club of St. Louis.

[Read April 9, 1884.]

In the history of the world the utilization of the wind as a motive power antedates the use of both water and steam for the same purpose.

The advent of steam caused a cessation in the progress of wind power, and it was comparatively neglected for many years. But more recently attention has been again drawn to it with the result of developing improvements so that it is now utilized in many ways.

The need in the west of a motive power where water power is rare and fuel expensive has done much to develop and perfect wind-mills.

Wind-mills, as at present constructed in this country, are of recent date.

The mill known as the "Eclipse" was the first mill of its class built. It is known as the "Solid-wheel, self-regulating pattern," and was invented about 17 years ago. The wind-wheel is of the rosette type, built without any joints, which gives it the name "solid wheel," in contradistinction to wheels made with loose sections or fans hinged to the arms or spokes, and known as "section wheel mills."

The regulation of the Eclipse Mill is accomplished by the use of a small adjustable side vane, flexible or hinged rudder vane and weighted lever as shown in Plate 1 (on the larger sizes of mills iron balls attached to a chain are used in place of the weighted lever), the side vane and weight on lever being adjustable can be set to run the mill at any desired speed. Now you will observe from the model that the action of the governing mechanism is automatic. As the velocity of the wind increases, the pressure on the side vane tends to carry the wind-wheel around edgewise to the wind and parallel to the rudder vane, thereby changing the angle and reducing the area exposed to the wind: at the same time the ever, with adjustable weight attached, swings from a vertical toward a horizontal position, the resistance increasing as it moves toward the latter position. This acts as a counterbalance of varying resistance against the pressure of the wind on the side vane, and holds the mill at an angle to the plane of the wind, insuring thereby the number of revolutions per minute required, according to the position to which the governing mechanism has been set or adjusted.

If the velocity of the wind is such that the pressure on the side vane overcomes the resistance of the counter weight, then the side vane is carried around parallel with the rudder vane, presenting only the edge of the wind wheel or ends of the fans to the wind, when the mill stops running.

This type of mill presents more effective wind receiving or working surface when in the wind, and less surface exposed to storms when out of the wind than any other type of mill. It is at all times under the control of an operator on the ground.

A 22-foot Eclipse Mill presents 352 square feet of wind receiving and working surface in the wind, and only 9½ square feet of wind resisting surface when out of the wind.

Solid-wheel mills are superseding all others in this country, and are being exported largely to all parts of the world, in sizes from 10 to 30 feet in diameter. Many of these mills have withstood storms without injury, where substantial buildings in the immediate vicinity have been badly damaged. I will refer to some results accomplished with pumping mills. In the spring of 1881 there was erected for Arkansas City, Kansas, a 14-foot diameter pumping wind-mill ; a 32,000-gallon water-tank, resting on a stone substructure 15 feet high, the ground on which it stands being 4 feet higher than the main street of the town. One thousand four hundred feet of 4-inch wood pipe was used for mains, with 1,200 feet of 1½-inch wrought-iron pipe. Three 3-inch fire hydrants were placed on the main street. The wind-mill was located 1,100 feet from the tank, and forced the water this distance, elevating it 50 feet. We estimate that this mill is pumping from 18,000 to 20,000 gallons of water every 24 hours. We learned that these works have saved two buildings from burning, and that the water is being used for sprinkling the streets, and being furnished to consumers at the following rates per annum : Private houses, $5 ; stores, $5 ; hotels, $10 ; livery stables, $15. At these very low rates, the city has an income of $300 per annum. The approximate cost of the works was $2,000. This gives 15 per cent. interest on the investment, not deducting anything for repairs or maintenance which has not cost $5 per annum so far.

In June, 1883, a wind water-works system was erected for the city of McPherson, Kansas, consisting of a 22-foot diameter wind-mill on a 75-foot tower, which pumps the water out of a well 80 feet deep, and delivers it into a 60,000 gallon tank, resting on a substructure 43 feet above the ground. Sixteen hundred feet of 6-inch, and 300 feet of 4-inch cast-iron pipe, furnish the means of distribution; eight 2½-in. double-discharge fire hydrants were located on the principal streets. A gate-valve was placed in the 6-inch main close to the elbow on lower end of the down pipe from the tank. This pipe is attached to the bottom of the tank; another pipe was run up through the bottom of tank nine feet (the tank being 18 feet deep), and carried down to a connection with the main pipe just outside the gate-valve. The operation of this arrangement is as follows : the gate valve being closed, the water cannot be drawn below the 9-foot level in tank, which leaves about 35,000 gallons in store for fire protection, and is at once available by opening the gate-valve referred to. The tank rests on ground about 5 feet above the main streets, which gives a head of 57 feet when the tank is half full. The distance from tank to the farthest hydrant being so short, they get the pressure due to this head at the hydrant, when playing two-inch, or 1¼-inch streams, with short lines of 2½-inch hose; this gives fair fire streams, for a town with few, if any buildings over two stories high. It is estimated that this mill is pumping from 30,000 to 38,000 gallons on an average every 24 hours. There is an automatic device attached to this mill, which stops it when the tank is full, but as soon as the water in the tank is lowered it goes to pumping again. The cost of these works complete to the city was a trifle over $6,000.

In November last a wind-mill 18 feet in diameter was erected over a coal mine at Richmond, in this State. The conditions were

as follows: The mine produces 11,000 gallons of water every 24 hours. The sump holds 11,000 gallons. Two entries that can be dammed up give a storage of 16,500 gallons, making a total storage capacity of 27,500 gallons. It takes 60 hours for the mine to produce this quantity of water, which allows for days that the wind does not blow. The average elevation that the water has to be raised is 65 feet, measuring from centre of sump to point of delivery. A record of 90 days shows that this mill has kept the mine free from water, with the exception of 6,000 gallons, which was raised in the boxes that the coal is raised in. The location is not good for a wind-mill, as it stands in a narrow ravine or valley a short distance from its mouth, which terminates at the bottom-lands of the Missouri River. This, taken in connection with the fact that the grit in the water cuts the pump-plunger packing so fast that in a short time the pump will not work up to its capacity, accounts for the apparent small amount of power developed by this mill. There has been some discussion of late in regard to the horse-power of wind-mills, one party claiming that they were capable of doing large amounts of grinding and showing a development of power that was surprising to the average person unacquainted with wind-mills, while the other party has maintained that they were not capable of developing any great amount of power, and have cited their performance in pumping water to sustain his argument. My experience has led me to the conclusion that pumping water with a wind-mill is not a fair test of the power that it is capable of developing, for the following reasons: A pumping wind-mill is ordinarily attached to a pump of suitable size to allow the mill to run at a mean speed in an eight to ten-mile wind. Now, if the wind increases to a velocity of sixteen to twenty miles per hour the mill will run up to its maximum speed and the governor will begin to act, shortening sail before the wind attains this velocity. Therefore, by a very liberal estimate, the pump will not throw more than double the quantity that it did in the eight to ten-mile wind, while the power of the mill has quadrupled, and is capable of running at least two pumps as large as the one to which it is attached. As the velocity of the wind increases this same proportion of difference in power developed to work done holds good.

St. Louis is not considered a very windy place, therefore the following table may be a surprise to some. This table was compiled from the complete record of the year 1881, as recorded by the anemometer of the United States Signal Office on the Mutual Life Insurance Building, corner of Sixth and Locust streets, this city. It gives the number of hours each month that the wind blew at each velocity, from six to twenty miles per hour during the year; also the maximum velocity attained each month.

The location of a mill has a great deal to do with the results attained Having had charge of the erection of a large number of these mills for power purposes, I will refer to a few of them in different States, giving the actual results accomplished, and leaving you to form your own opinion as to the power developed.

In 1877 a 25-foot diameter mill was erected at Dover, Kansas, a few miles southwest of Topeka. It was built to do custom flour and feed grinding, also corn shelling, and is in successful operation at the present time. We have letters frequently from the owner; one of recent date

Complete Wind Record at St. Louis for the Year 1881.

YEAR 1881. MONTHS.	No. hours wind blew 6 miles or over...		No. hours wind blew 8 miles or over....		No. hours wind blew 10 miles or over...		No. hours wind blew 12 miles or over...		No. hours wind blew 14 miles or over...		No. hours wind blew 16 miles or over...		No. hours wind blew 18 miles or over...		No. hours wind blew 20 miles or over...		Maximum velocity during each month.
	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	
Jan.......	545	45	429	45	289	00	198	15	131	30	87	15	56	00	38	45	31
Feb	619	30	533	15	449	15	374	15	287	00	207	15	151	15	110	30	32
March....	604	15	534	30	449	45	368	45	296	30	243	45	191	00	158	45	37
April... .	577	15	468	45	342	45	359	30	175	00	121	00	62	45	36	00	28
May	553	00	375	00	226	15	138	00	74	45	42	30	23	45	11	30	31
June......	614	15	463	45	303	30	215	15	123	45	76	30	29	45	17	45	32
July......	556	45	378	00	228	15	136	15	55	30	22	30	6	00	2	30	22
Aug......	536	30	345	00	176	00	80	30	35	45	22	15	17	15	15	00	34
Sept......	564	15	445	45	326	45	224	45	145	30	96	45	70	00	46	45	30
Oct.......	617	30	501	45	368	45	363	00	170	00	95	45	49	30	27	45	27
Nov	642	45	537	30	428	45	328	30	226	00	151	45	100	30	74	00	30
Dec	592	15	516	30	390	00	308	45	224	45	167	45	110	45	67	00	30
Totals..	7,024	00	5,529	30	3,981	00	2,995	45	1,946	00	1,335	00	868	30	606	15	......
Max. for year....	....		....		....		....		....		....		....		....		37

states that it has stood all of the "Kansas zephyrs," never having been damaged as yet. On an average it shells and grinds from six to ten bushels of corn per hour, and runs a 14-inch burr-stone, grinding wheat at the same time. During strong winds it has shelled and ground as high as thirty bushels of corn per hour. Plate 2, is from a photograph of this mill and building as it stands. One bevel pinion is all the repairs this mill has required. In the spring of 1880 there was erected a 25-foot diameter mill at Harvard, Clay County, Neb. After this mill had been running nineteen months we received the following report from the owner: "During the nineteen months we have been running the wind-mill it has cost us nothing for repairs. We run it with a two-hole corn-sheller, a set of 16-inch burr-stones and an elevator. We grind all kinds of feed, also corn-meal and Graham flour. "We have ground 8,340 bushels, and would have ground much more if corn had not been a very poor crop here for the past two seasons; besides, we have our farm to attend to and cannot keep it running all the time that we have wind. We have not run a full day at any time, but have ground 125 bushels in a day. When the burr is in good shape we can grind 20 bushels an hour, and shell at the same time in the average winds that we have. The mill has withstood storms without number, even one that blew down a house near it, and another that blew down many smaller mills. It is one of the best investments any one can make."

The writer saw this mill about 60 days ago, and it is in good shape and doing the work as stated. The only repairs that it has required during four years was one bevel pinion put on this spring.

The owner of a 16-foot diameter mill, erected at Blue Springs, Neb., says: "That with a fair wind it grinds easily 15 bushels of corn per hour with a No. 3 grinder, also runs a corn-sheller and pump at the same time, and that it works smoothly and is entirely self-regulating."

The No. 3 grinder referred to has chilled iron burrs and requires from 3 to 4 horse-power to grind 15 bushels of corn per hour. Of one of these 16-foot mills that has been running since 1875 in Northern Illinois, the owner writes: "In windy days I saw cord-wood as fast as the wood can be handled, doing more work than I used to accomplish with five horses."

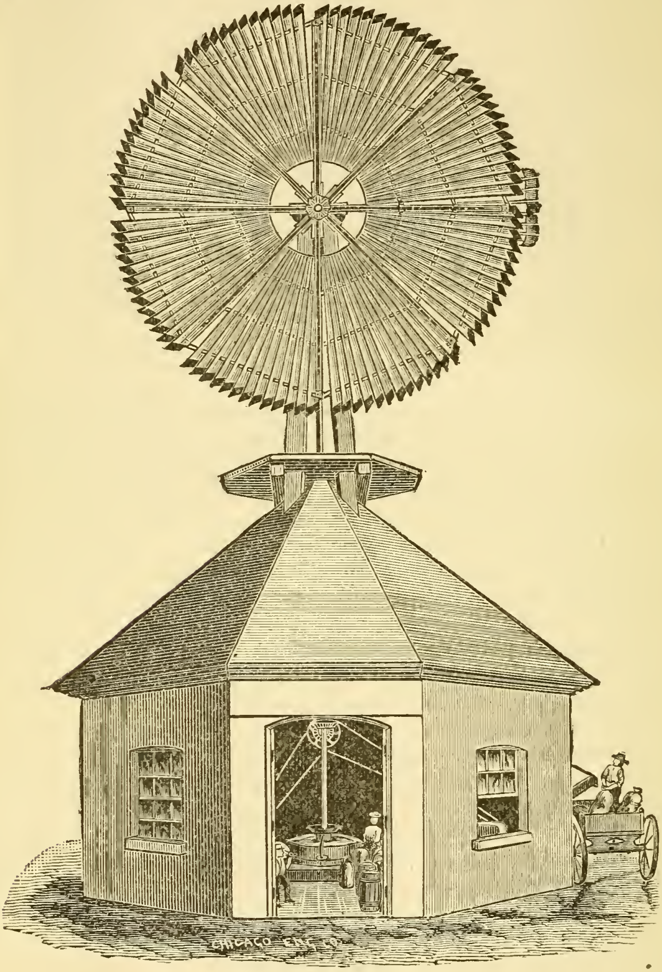


Plate 2.

The owner of one of these mills, 20 feet in diameter, running in the southwestern part of this State, writes that he has a corn-sheller and two iron grinding mills with 8-inch burrs attached to it; also a bolting device; that this mill is more profitable to him than 80 acres of good corn land and that it is easily handled and has never been out of order. The following report on one of these 16-foot mills, running in northern Illinois, may

be of interest: This mill stands between the house and barn. A connection is made to a pump in a well-house 25 feet distant and is also arranged to operate a churn and washing machine. By means of sheaves and wire cable, power is transmitted to a circular saw 35 feet distant. In this same manner power is transmitted to the barn 200 feet distant, where connection is made to a thresher, corn-sheller, feed-cutter and fanning-mill. The corn-sheller is a three horse-power, with fan and sacker attached. Three hundred bushels per day has been shelled, cleaned and sacked. The threshing machine is a two horse-power with vibrating attachment for separating straw from grain. One man has threshed 300 bushels of oats per day and on windy days says the mill would run a thresher of double this capacity. The saw used is 18 inches diameter, and on windy days saws as much wood as can be done by six horses working on a sweep power. The owner furnishes the following approximate cost of mill with the machinery attached and now in use on his place:

1 16-foot power wind-mill, shafting and tower	$385
1 Two-horse thresher	70
1 Three-horse sheller	38
1 Feed grinder	50
1 18-inch saw, frame and arbor	40
1 Fanning-mill	25
1 Force-pump	27
1 Churn	5
1 Washing machine	15
Belting, cables and pulleys	45
Total	$700

The following facts and figures furnished by the owner will give a fair idea of the economic value of this system, as compared with the usual methods of doing the same work. On the farm where it is used, there are raised annually an average of sixty acres of oats, fifty acres of corn, twenty acres of rye, ten acres of buckwheat.

	Bushels
The oats average, say 30 bushels per acre	1,800
Corn " 30 " "	1,500
Rye " 20 " "	400
Buckwheat " 20 " "	200
Grinding for self and others	1,000

It will cost to thresh this grain, shell the corn, and grind the feed with steam power	$285
And sawing wood, 12½ cords	18
Pumping, one hour per day, 365 days	36
Churning, half hour per day, 200 days	10
Washing, half day per week, 26 days	26
Total	$375

This amount is saved, and more too, as one man, by the aid of the wind-mill, will do this work in connection with the chores of the farm, and save enough in utilizing foul weather to more than offset his extra labor, cost of oil, etc., for the machinery. The amount saved each year is just about equal to the cost of a good man. Cost of outfit, $700—just about equal to the cost of a good man for two years, consequently, it will pay for itself in two years. Fifteen years is a fair estimate for the lifetime of mill with ordinary repairs.

The solid wheel wind-mill has never been built larger than 30 feet in diameter. For mills larger than this, the latest improved American mill is the "Warwick" pattern.

A 30-foot mill of this pattern, erected in 1880, in northwestern Iowa, gave the following results, as reported by the owner :

"Attachments as follows : One 22-inch burr ; one No. 4 iron feed mill; one 26-inch circular saw ; one two-hole corn-sheller ; one grain elevator ; a bolting apparatus for fine meal, buckwheat and graham, all of which are run at the same time in good winds, except the saw or the iron mill ; they being run from the same pulley can run but one at a time. With all attached and working up to their full capacity, the sails are often thrown out of the wind by the governors, which shows an immense power. The machines are so arranged that I can attach all or separately, according to the wind. With the burr alone I have ground 500 bushels in 48 consecutive hours, 100 bushels of it being fine meal. I have also ground 24 full bushels of fine meal for table use in two hours. This last was my own, consequently was not tolled. This was before I bought the iron mill, and now I can nearly double that amount. I saw my fire wood for three fires ; all my fence posts, etc. My wood is taken to the mill from 12 to 15 feet long and as large as the saw will cut by turning the stick, consequently the saw requires about the same power as the burrs. With a good sailing breeze I have all the power I need, and can run all the machinery with ease. Last winter I ground double the amount of any water mill in this vicinity. I have no better property than the mill."

A 40-foot mill, erected at Fowler, Indiana, in 1881, is running the following machinery :

"I have a universal wood-worker, four side, one 34-inch planer, jig saw and lathe, also a No. 4 American grinder, and with a good, fair wind I can run all the machines at one time. I can work about four days and nights each week. It is easy to control in high winds."

A 60-foot diameter mill of similar pattern was erected in Steele County, Minnesota, in 1867. The owner gives the following history of this mill :

"I have run this wind flouring mill since 1867 with excellent success. It runs 3 sets of burrs, one 4 feet, one 3½ feet and one 33 inches. Also 2 smutters, 2 bolts and all the necessary machinery to make the mill complete. A 15-mile wind runs everything in good shape. One wind wheel was broken by a tornado in 1870, and another in 1881 from same cause. Aside from these two, which cost $250 each, and a month's lost time, the power did not cost over $10 a year for repairs. In July, 1883, a cyclone passed over this section wrecking my mill as well as everything else in its track, and having (out of the profits of the wind-mill) purchased a large water and steam flouring mill here, I last fall moved the wind-mill out to Dakota, where I have it running in first-class shape and doing a good business. The few tornado wrecks make me think none the less of wind-mills, as my water power has cost me four times as much in 6 years as the wind power has in 16 years."

There are very few of these large mills in use in this country, but there are a great many from 14 to 30 feet in diameter in use, and their numbers are rapidly increasing as their merits become known. The field for the use of wind-mills is almost unlimited, and embraces pumping water, drainage, irrigation, elevating, grinding, shelling and cleaning grain, ginning cotton, sawing wood, churning, running stamp mills, and charg-

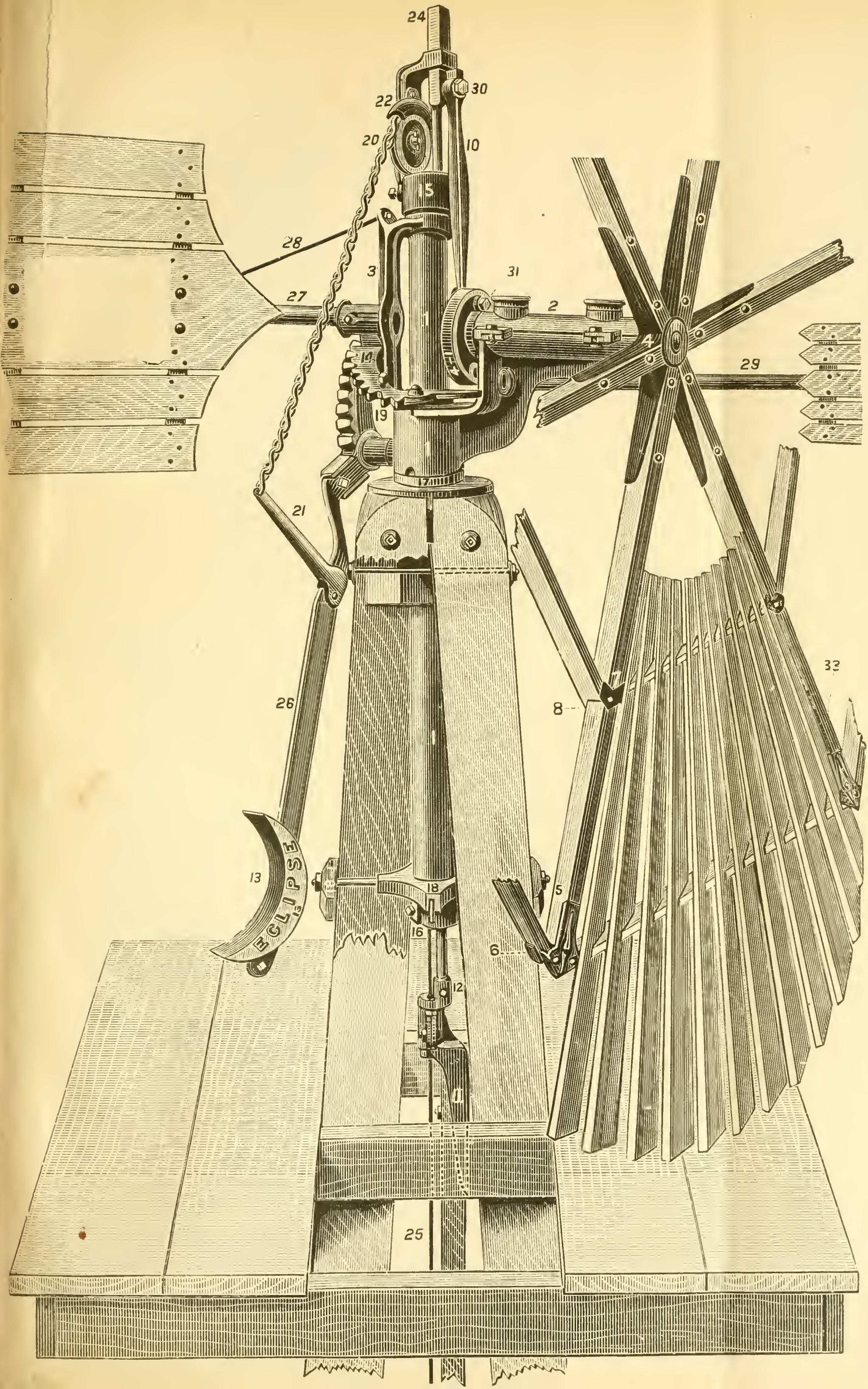


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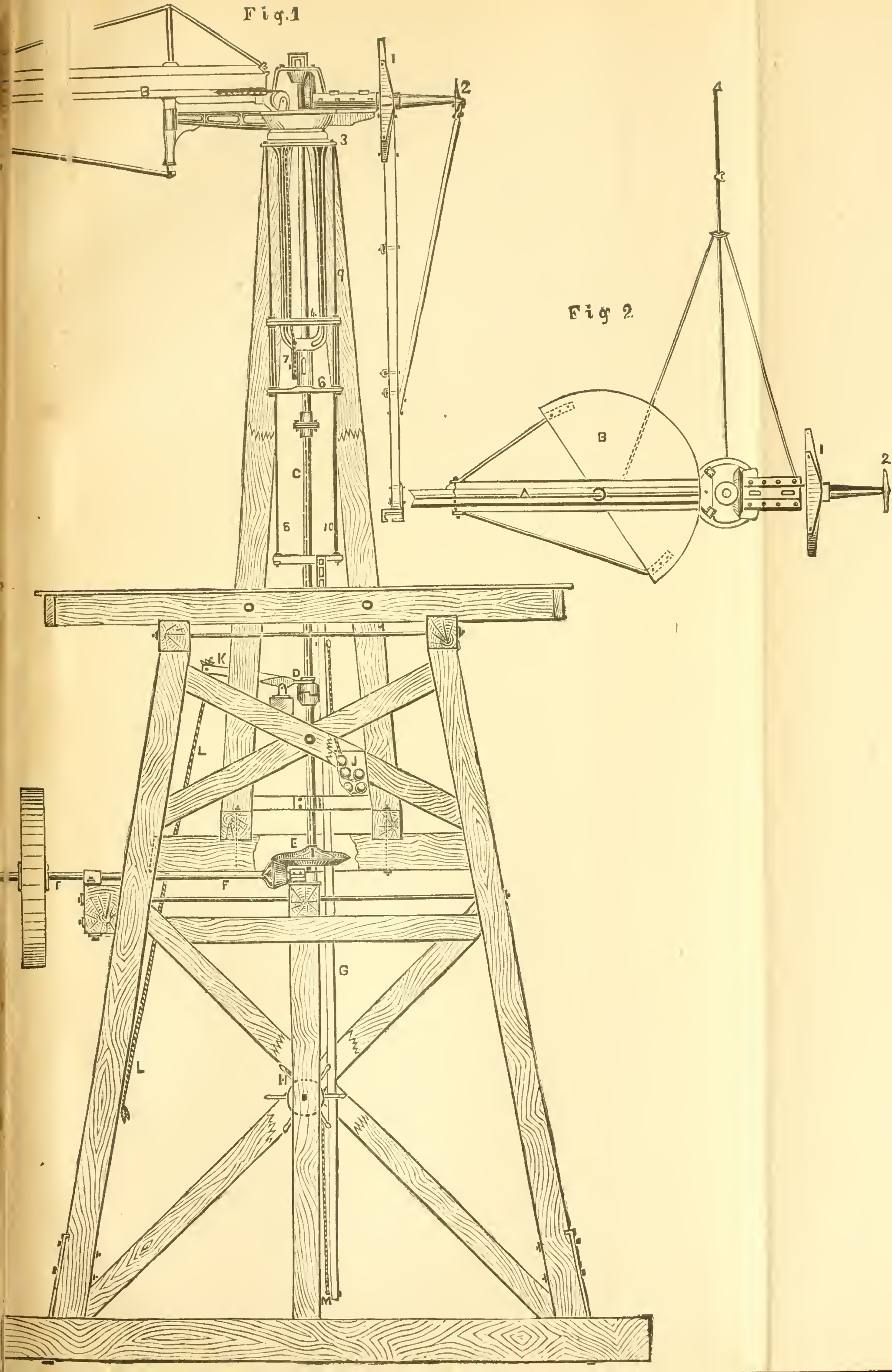
Fig.1



ing electrical accumulators. This last may be the solution of the St. Louis gas question.

In the writer's opinion the settlement of the great tableland lying between the Mississippi Valley and the Rocky Mountains and extending from the Gulf of Mexico to the Red River of the North, would be greatly retarded, if not entirely impracticable, in large sections where no water is found at less than 100 to 500 feet below the surface, if it were not for the American wind-mill; large cattle ranges without any surface water have been made available by the use of wind-mills. Water pumped out of the ground remains about the same temperature during the year, and is much better for cattle than surface water. It yet remains in the future to determine what the wind-mill will not do with the improvements that are being made from time to time.

Plate 3 shows the details of the Eclipse geared mill from 16 to 30 feet in diameter. These mills are used mostly on farms, plantations, elevators, small shops, and for drainage and irrigation.

Figure 1 shows an elevation of a four-post tower, with mill and shafting mounted and broken away in places to show the working parts to better advantage. This is designed only to show the working parts of mill and machinery in position, and not to show any plan of tower.

Figure 2 is a plan view of mill, showing position of the main and side vanes when the mill is in the wind.

A is tail bar and *B* is circle board attached to same; *C* is upright shaft; *D* is clutch coupling on upright shaft; *E* is lower gear; *F* is line shaft; *G* is shut-off pole; *H* is shut-off reel; *J* is regulating weights or balls, and box which receives them; *K* is lever which operates the clutch *D*; *L* is rope attached to lever *K*, by means of which clutch *D* can be operated from below.

When mill is in use it is regulated by the pressure of the wind on the side vane; this, in heavy wind or gusts, carries the wheel more or less out of the wind. In doing this it raises the shut-off pole *G*, to which are attached regulating weights *J*, by means of chain passing around circle board *B*, thus lifting balls or weights out of box, and throwing the weight on shut-off pole *G*. This acts as a counter-weight or balance to the side vane, and as the wind slackens, these weights return the wheel back, facing the wind again. When it is desired to stop the mill, wind up the chain on reel *H*, thus raising up the shut-off pole *G*, and through chains on circle board *B*, throwing the wheel around edge to the wind.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF ST. LOUIS.

MAY 8, 1884:—The St. Louis Civil Engineers' Club met at the Mercantile Library, thirty members being present. The minutes of the last meeting were read and approved.

The following names were proposed for membership: Prof. F. E. Nipher, by W. B. Potter and J. B. Johnson; Willard Beahan, by D. C. Humphreys and K. Tully; C. E. Jones, by C. F. White and J. B. Johnson; H. W. Sebastian and H. W. Baker, by A. H. Blaisdell and D. C. Humphreys. The following gentlemen were elected members: Charles Foster, Hubert Taussig and Dr. Wellington Adams.

A communication was read from the general ticket agent of the Missouri Pacific Railway giving rates for a special train for an excursion on the Iron Mountain road.

The offer by the Mercantile Club of a room in which to hold meetings, was taken up and the offer accepted with thanks, and the President and Secretary authorized to call the meetings of the club there at their discretion.

The name of A. W. Smith was dropped from the rolls for non-payment of dues, and the name of F. A. Churchill erased for never having qualified.

Robert Moore and Robert E. McMath each read further discussions on the subject of the combined versus the separate systems of sewers for large cities, continuing the arguments of the general discussion of several weeks ago.

Mr. J. B. Johnson then read a paper on "Protection of the Lower Mississippi River from Overflow," which was generally discussed.

[*Adjourned.*] J. B. JOHNSON, Secretary.

WESTERN SOCIETY OF ENGINEERS.

MAY 6, 1884:—The 185th meeting was held at 4 P. M., President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Jones, for the committee on extending courtesies to the American Institute of Mining Engineers, reported that they had met with the Reception Committee of the Institute, and had been made members of that committee. They found that the arrangements already made precluded the possibility of offering anything by this Society, except the use of its rooms to members of the Institute; all the time of the convention being fully provided for.

It was voted that this committee be authorized to make suitable arrangements for the use of the Society's rooms for the purposes required.

Mr. Cregier stated that, on behalf of the city, he would offer to the Institute an excursion to the Waterworks Crib.

The Secretary reported the receipt of cabinet photograph portraits from Messrs. Booth, Dodge, Greeley, Tutton and Wright.

A paper for the next meeting was announced by the Committee on Surveys and Topography, "The Proper Mode of Sub-dividing a Full Government Quarter Section," by Mr. Z. A. Enos.

At the suggestion of Mr. Cregier it was voted that a committee of three be appointed to draft a resolution of sympathy for Gen. W. Sooy Smith, Past President of the Society, in the recent death of his wife.

The Chair appointed Messrs. Wright, Booth and Randolph as this committee.

Mr. Lotz exhibited and explained a series of drawings, thirty-seven in number, made for the Weehawken Elevator, to be built for the West Shore & Ontario Terminal Co., at Weehawken, N. J.

Mr. Wright, for Committee on Transportation, read a short paper, "A Problem in Curves," which was ordered printed.

The committee appointed to prepare a resolution of sympathy, reported the following, which was adopted:

To Past-President W. Sooy Smith: Expressions of sympathy often fall coldly upon the ear made dull by a great sorrow, but remembering what you have been to this Society, and entertaining as we do, both as individuals and as a corporate body, the highest esteem for you, we, the Western Society of Engineers, cannot refrain from tendering to you, in this your time of sorrow, our heartfelt sympathy, which, we trust, may not seem like an intrusion upon a grief with which the stranger may not intermeddle.

Resolved, That the Secretary be instructed to transmit a copy of these resolutions to Gen. Sooy Smith.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

AN INVITATION

TO ATTEND THE PHILADELPHIA MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

A cordial invitation has been extended to all members of the Association of Engineering Societies to attend the meeting of the Section of Mechanical Science (D) of the American Association for the Advancement of Science, to be held in Philadelphia, September 3–10, 1884.

The members of our associated societies are further invited to join the association (if not already members) and to take an active part in the proceedings.

The British Association, which meets at Montreal this year, is expected to attend in a body, and the Electrical Exhibition, under the auspices of the Franklin Institute, occurs at the same time.

Section D is especially devoted to the applications of sciences to the arts, and includes all departments of engineering.

Members, actual or prospective, who intend presenting papers to be read before this section, can obtain the proper blanks from the Secretary, Prof. J. Burkitt Webb, Cornell University, Ithaca, N. Y., on which to offer the titles and abstracts of their papers, which should be presented as early as possible.

The above invitation comes signed by R. H. Thurston, Chairman, and J. Burkitt Webb, Secretary of the Section.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. III. July, 1884. No. 9.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

PROTECTION OF THE LOWER MISSISSIPPI VALLEY FROM OVERFLOW.

By J. B. Johnson, Member of the Engineers' Club of St. Louis.
[Read May 7, 1884.]

By Lower Mississippi Valley is here meant that portion of the valley below Cairo, lying between the bordering highlands and subject to overflow in time of high water. The extent of this area is enormous, and perhaps has no parallel in any civilized portion of the globe. It is a region covering 7½ degrees of latitude (from 29½° to 37°), and has an area of some 20,000 square miles, being equal to the combined areas of Massachusetts, Connecticut, and New Jersey, or half as large as the State of Ohio. In other words, it is a fertile region of bottom land 500 miles long and 40 miles wide. A large portion of this region, perhaps half of it, would be unfit for agricultural purposes, even though it were protected from flood waters. But if this liberal deduction be made, there remains a strip of land 500 miles long and 20 miles wide, unexcelled in fertility, which might be cultivated with great profit if it were not subject to frequent overflow. The staple products of this region are cotton and sugar. Cotton is an annual, and should be planted in February or March, while sugar-cane is a perennial, and is killed if covered with water for a few weeks. It then requires two years to bring a new stand to maturity, and the planter has no income during this period.

Great floods usually come at Cairo in February and March, and in the lower parts of the valley in March and April. If the flood gets off of bottom land in time to put in a crop, the planter is benefited in the increased yield per acre. If the flood lasts through March he gets at best a small yield, and if it lasts through April he will plant none at all. The sugar-planter is greatly damaged by overflow, let it come when it will.

The source of the greatest floods is in the Ohio Valley, and the occasion of them is the melting of the winter's snows, accompanied by heavy spring rains, both north and south of the Ohio River. If these come when the ground is still frozen, the water is almost all poured into the streams. So far as the settling up of country contributes to the rapid discharge of surface waters, just so far does this cause contribute to great

floods. I believe there is no evidence that the rainfall in the Mississippi Valley is either increasing or diminishing in quantity, and, therefore, any change in the frequency of great floods must come from a change in the conditions of surface discharge. Since these conditions certainly do change, in changing from a wild, wooded or prairie country, to a cultivated state, it is fair to presume that there is a corresponding change in the frequency and heights of great floods. The variables that enter into this problem are so numerous, and so lawless in their action, that an argument from experience can only be founded after a long period of careful observation. As a matter of fact, however, for three successive years, 1882, 1883, and 1884, we have had unusually large floods on the Mississippi River below Cairo, and the data have now become accessible for the study of the first of these, 1882, not only as to the stage of water, but as to the actual quantities discharged.

The Mississippi River Commission had five parties in the field through the whole of the year 1882, taking daily observations on the quantity of water discharged per second. They were distributed as follows: At Paducah, Ky., on the Ohio, just below the mouth of the Tennessee River, and some 40 miles above Cairo; at Columbus, Ky., 21 miles below Cairo; at Helena, Ark., just below the mouth of the St. Francis; at Hays Landing, La., 11 miles below Lake Providence and 46 miles above Vicksburg; and at Red River Landing, just below the mouth of Red River. These locations were remarkably favorable for studying the action of the great flood of that year. In addition to these permanent parties there were sent into the field at the top of the flood three temporary parties to observe the escape of the flood waters over the banks and through breaks in the levees from Cairo to New Orleans. One of these parties made a cross-section survey across the St. Francis Bottom, and determined the amount of flood water passing that section. The other two parties observed the quantity of water passing out of the channel into the swamp from Cairo to New Orleans. Some of this data is now published in the report of the commission for 1883. From this source we extract the following:

At Columbus, with 1,600,000 cubic feet per second passing in the channel, we have 200,000 cubic feet per second passing through the swamp.

At Memphis, with 1,150,000 cubic feet per second passing in the channel, we have 650,000 passing in the swamp.

At Helena, with 1,510,000 cubic feet per second passing in the channel, we have 360,000 passing in the swamp.

At Hays Landing, with 1,000,000 passing in the channel, there was another million passing in the swamp.

At Red River, with 1,600,000 passing in the channel, there was 600,000 passing outside, 300,000 of which passed down the Atchafalaya.

If all this flood water had been confined to the channel, there would have been added to the already overflowing river at the head of the St. Francis Basin 200,000, all along the central portions of this front some 600,000, and at the lower end 360,000 cubic feet per second.

Along the central portions of the Yazoo front there would have been added some 800,000 to 1,000,000, and at the lower end, or at Vicksburg, some 400,000 cubic feet per second.

At Red River there would have been added some 300,000, and at New Orleans about 1,000,000 cubic feet per second to the maximum amounts ever carried by the channel in these parts, even when overflowing the levees along its banks.

This is the present status of the lower Mississippi Valley, and now the important question arises, what shall be done about it?

There are in general three methods of treatment open, each of which is feasible as an engineering problem. In addition to these we have Nature's method, or rather want of method, in providing no artificial barriers to overflow. This latter demands no outlay and allows the flood waters to find auxiliary passages to the Gulf, first through the St. Francis Swamp, then through the Yazoo, and then through Bayou Maçon and the Atchafalaya bottoms. This policy has many advocates amongst river men, and some amongst planters themselves. Before levees were built on the Mississippi River, there were innumerable branches and bayous opening off from the main channel, having a depth of many feet below the natural surface of the banks and discharging into the back swamp regions. These began to draw from the channel before the stage reached the top of the bank, and so overflows were less frequent and the maximum stages lower. These are now mostly closed, so that no water escapes from the channel except over the top of the bank. This it now freely does over the whole of the St. Francis front, and over the upper third of the Yazoo front, or as far down as Sunflower Landing, 120 miles by river below Memphis. From there to New Orleans the swamps are leveed out, except the Atchafalaya River itself, which opens out of the Mississippi at the mouth of the Red River. This is now really the continuation of Red River, so that at low stages there is no connection between the Red and Atchafalaya rivers and the Mississippi, the Red River discharging its water down the Atchafalaya to the Gulf. At higher stages the water flows from the Mississippi into the Atchafalaya, or *vice versa*, according to the relative stages of the two streams.*

It is generally claimed, however, by planters in these bottoms, that this policy of neglect would make agriculture so unprofitable that it would generally be abandoned, and that these regions would soon again become trackless forests, better fitted for habitations of bear, deer, and alligator than for man. In fact, these bottoms are now cultivated only in proportion to the degree of protection obtained from flood waters. Thus, in the great St. Francis Basin, where there is practically no protection, there is no land cultivated except narrow strips along the river fronts which rise to near high-water mark. In the Yazoo Bottom, the higher portions are pretty generally under cultivation, but as much more would be cultivated if there was assurance of complete protection from high water.

Southwestern Louisiana, which before and during the war was considered the garden spot of the State, has now mostly gone wild again on account of the overflows caused by the increased discharge of the Atchafalaya.

Nature's treatment, then, or that of no confinement, seems to lead to

* See map accompanying a paper entitled "Great Floods on the Lower Mississippi" in the Associated JOURNAL for February, 1883.

nature's growth on the soil subject to the river's overflow. In other words, the river will be abandoned by the industrious, thriving classes, leaving, perhaps, a scattered, shiftless population who, when the river is down will see no necessity of leaving, and when it is up will find it impossible to get away.

As to the effect of this treatment on improvement of navigation, it would, I think, be beneficial, or at least not injurious. Notwithstanding all that has been said on this subject, from Capt. Eads and the Mississippi River Commission, who ought to know a great deal about the subject, down to the newspaper editor who evidently knows nothing about it, there are still a few engineers who have a direct, personal knowledge of the subject, who believe that *in the present state of the river*, any additional confinement which raises the high water stage is evil, and only evil, so far as low-water navigation is concerned. The argument is simply this : Since the bars are all formed at high stages, and the higher the stage the higher the bars are built, so any addition to the high stages by means of levees, increases the bar-building influence. That is, in high stages the river always scours in deep places and fills on the shoals, which is exactly what we wish to prevent. The facts here stated cannot be gainsaid. They result from the inordinate variations in the width of the river. To try to scour off the bars, therefore, by building levees on the banks, as they now are, is like trying to depress a ridge by piling earth on top of it. If no levees are built, the stage is kept several feet lower, and the bar-building process checked so much sooner, and prosecuted with so much less energy.*

But here we are met by the counter statement, that when the flood waters escape over the banks, the current in the channel is checked and the water drops a part of its sediment, and thus bars are formed. This is, in substance, the whole argument in favor of levees, as a means of bar prevention. This is also the popular conception of the problem, and has nowhere been more strongly defended than before the Congressional committees. It is worth our while to examine this argument a little :

1. The river bed is a succession of narrow, deep and long pools, and short, wide shoals, the pools generally being in the bends, and the shoals on the crossings.

2. At low stages the slow current is in the pool, and the rapid current on the crossing. At high stages the more rapid current is in the narrow pool and the slower current on the wide crossing.

3. This variation in mean velocity of the water from pool to shoal, and *vice versa*, is enormous, being as much as 250 per cent. (4 feet to 10 feet per second) on the Plumb Point reach. (See Rep. Miss. Riv. Com. 1881, p. 120, pl. 7.)

Thus, with a 6-mile current in the pool, and a 3-mile current on the crossing below, it is evident that sand will be washed out of the deep pool and deposited on the succeeding shoal. This occurs at high stages, and if the high stage continues long enough this action will continue until the cross sections are so nearly equalized that a uniform velocity is

* For a full discussion of this subject see a paper by Robt. E. McMath, read before this Club February 27, 1884, and printed in the January-February Number of the Associated JOURNAL.

attained. Again with a 2-mile current on the crossing, and a 1-mile current in the pool below, sand will be washed off the shoal crossing and deposited in the pool. This occurs at low stages, and if the low stage continues long enough, this action will go on until a uniform flow is reached.

4. Whatever checking of velocity there may be, due to flow over the bank (and there is no evidence that there is any such action on the Mississippi, below Cairo, due to overflow simply), it must be very slight, and if it should give rise to a deposit at all, it would be very small and would be made immediately below the point where the diminution occurred, whether shoal or pool, whereas the deposit of discontinuous suspended matter, above described, is all on the shoal places in high stages.

5. There are two ways in which velocity may be checked, which must be kept very distinct in our minds. We may have two different velocities in neighboring sections at the same time, or two different velocities at the same section at different times. Thus we may have a 5-mile current here in a pool, and a 3-mile current on the crossing a few miles below. This is of the first kind, is due to variable cross section, and causes sand-bars. Or we may have a 5-mile current here to-day, and a few days hence but a $4\frac{3}{4}$-mile current at this same place. If this latter velocity were found at the same or a higher stage than the former, and there was at the same time a general overflow, some would attribute the diminution to the fact of overflow. Suppose we grant this (which we do not), is there anything in this phenomenon tending to cause a deposit on the bars? This general diminution has occurred over long reaches of river, and is exactly analogous to a diminished velocity due to a falling stage. The average velocity over long reaches is not significant as affecting the sand-bars, but only the relative velocities at successive sections. If the general average velocity has been diminished simply, then the wide variations of velocity at neighboring sections are brought nearer together, and the bar-building energy is diminished exactly as is known to occur at lower stages. Any diminution of velocity, therefore, as indicated by a discharge curve, which simply shows the change of velocity at a given locality at different times, has no significance as affecting the height of sand-bars.

6. If there is a deposit of sediment in proportion to the checking of the velocity between two points, which is doubtless nearly true, then if the checking of velocity due to variable cross section is 50 per cent., and the checking of velocity between these two points, due to overflow, is 5 per cent., then the deposit causing sand-bars, due to varying widths, is ten times as great as that due to overflow. If, however, this loss due to overflow has no necessary locality relation to the loss due to varying cross section, then the two are as likely to be compensating as cumulative in their effects. If they are compensating, then the overflow is a positive benefit, for it then checks the velocity where it is inclined to be too rapid, and so tends to equalize the flow. It is highly probable that this is generally its effect. Most of the water that goes over the bank leaves the river in the bends, where the velocity at this stage is most rapid, and if this checks the velocity at all it does it where it most needs checking.

7. This estimate of 5 per cent. of loss in velocity due to overflow is more than is indicated by any of the discharge curves on the Mississippi below Cairo. In fact the Columbus and Red River curves do not indicate any actual diminution of velocity whatever due to overflow, and the observations at Helena are so discrepant that no certain conclusion can be drawn. The overflow was large in the vicinity of all these sections. But even if this diminution of velocity of 5 per cent. be allowed, for the sake of the argument, then by confining the water we increase the energy of a bar-building function which enters with a coefficient of ten, and diminish the energy of another function which is more likely to be with us than against us, but which only enters with a coefficient of one.

That is, we have a probable losing at the spigot, with a certain losing at the bung.

7. We may say, therefore, that troublesome sand-bars are due to *local causes*, and these are mainly extraordinary variations in width in neighboring sections of the river. The remedy, evidently, is to narrow the channel over these wide reaches. This the Commission is doing, and is doing it probably as well as can be done. The Commission, however, favor levee building as an aid to bar removal, and in this we think they err.

8. Our position then is, that with the present variations in the width of the channel, levees increase the fluctuations in velocity at high stages, and therefore increase the deposit on the bars. The levees do increase the energy of the river, but it is like increasing the energy of a wild or frightened horse. The river has already entered upon its mischievous work when it nears the top of the bank, and to increase its energy now is only to make a bad matter worse. When the wayward spirit of this wild steed has been broken and curbed, when we succeed in bridling him, harnessing him and holding him within the traces, and when he has ceased these wild pitchings and chargings and balkings, then, and not till then, may his energy be increased indefinitely with advantage.

But the object of this paper is not to discuss methods of improvement of low water navigation, but rather to study the subject of protection of the swamp region from overflow. The first method of protection, or rather the absence of method above described, though I believe conducive to the interests of navigation, would prove totally destructive to the agricultural interests of the valley. If the government will so regulate the width of the channel, however, that the building of levees will not prove any great injury, which will in time be done, then a compromise might be effected, and the inhabitants of the valley allowed to protect themselves by leveeing out the river from these regions from Cairo to the Gulf.

When this stage of advancement is reached, then these three methods of protection are open, all of which are feasible in an engineering sense.

First. The system now in vogue, or levees confining ordinary floods but great floods always breaking through them.

Second. The enormously expensive system of levees high enough to contain the highest floods.

Third. A new system, lately adopted in France, of building levees to

contain ordinary floods (such levees as are now built, for instance), with waste weirs, through which the surplus waters of great floods may escape without damaging the levees.

These three systems are all equally feasible as engineering projects. The questions of cost, benefit and injury remain to be discussed.

The first system, that now in vogue, we of course understand. It is both expensive and unsatisfactory. It is a protection that costs millions of dollars, and yet does not protect. For three successive years these barriers have given way in scores of places, and a very large part of the country that contributes to their expense has been flooded out as thoroughly as though the levees had not been there. This system is therefore far from satisfactory to these people. It is also very expensive and troublesome. No one who has not witnessed it can have any adequate conception of the almost superhuman efforts put forth by these lowlanders when they see a flood coming that is likely to overtop their frail barriers. Sometimes they succeed in keeping the savage waters at bay, but oftener, in such a case, their sleepless enemy finds a weakest point, and, perhaps under cover of darkness and with wind and wave to aid him, he mounts to the top of their low defense, and all is lost.

Thus, in 1882, many miles of levee that was considered high enough and strong enough to keep back any flood that was likely to come, were washed away. In estimating the cost of this system we must include not only the cost of repairing the broken levees, but the damage done to private and corporation interests. These latter are practically incalculable. The repairing of the broken levees themselves would make this a very expensive system.

The second expedient which we have mentioned is to build the levees high enough and strong enough to withstand the greatest flood that would likely come upon them. For this purpose the flood of 1882 might fairly be taken as a maximum flood, for it is doubtless the greatest on record. If we should allow a margin of two or three feet above the probable height the flood of 1882 would have reached if it had all been confined to the channel, we should probably have a levee that would hold any flood that would ever come. To examine the cost of this system we must decide what would be the probable heights to which such levees would have to be carried. On this subject we now have as accurate data on which to base our estimates as will ever be obtained until the levees are actually built and the resulting flood line observed. For the greatest flood on record (1882) the discharge was observed both in and out of the channel at Columbus, Helena, Hays Landing, and Red River. The discharge tables, with their accompanying curves, are given in the current report of the commission. This report also contains computed discharges for every day in the year 1882 at three other points where elaborate discharge observations had been taken in previous years. These stations are Fulton, Tenn., Memphis, and New Orleans. This gives us seven points on the river below Cairo at which the daily discharge is known throughout the flood period of 1882. If now we plot the discharges in cubic feet per second, and the gauge heights, as the coördinates of a line, we will obtain a smooth curving line which we call a discharge curve. Since we

have the actual observed values of both these coördinates up to a stage even with the tops of the levees, being many feet above the top of the bank; and since the regularity of the curve through a variation of stage of 40 or 50 feet is so marked as to indicate a fixed law of dependence between discharge and stage, we evidently do no violence to the facts when we simply extend this curve a few feet further, say one-fifth of its present length, *and so predict what the stage would be for a given increase in the discharge.* This is the same kind of an argument that is used to determine the orbit of a heavenly body, only there the astronomer observes but a very small portion of the orbit, say 20 per cent, and predicts or computes the remaining 80 per cent., while here we have observed the 80 per cent., and only predict or compute the remaining 20 per cent. This is, therefore, the safest possible argument to use in determining what cannot be directly observed. The only assumption is, that as the river has done from a zero to a 40 or 50 foot stage, so it will continue to do for a few feet further, if the conditions remain the same. And the conditions do remain the same if the levees are left in the same position and simply raised so high that no water will escape.

It has been thought necessary to enlarge on the nature of this argument, because the conclusions arrived at are so important, and to many they are so surprising as to seem incredible. This is the line of argument used by the President of the river commission in his exceptions to the report of 1883. I will give General Comstock's conclusions as to the increased height the river would have attained if all the water had been confined between levees in the flood of 1882. The estimates are but approximate, but I think err in being too small rather than too large. (See Rep. of Miss. Riv. Com. 1883, p. 25.)

At Columbus, Ky., there would have been added 200,000 cubic feet per second to the channel discharge, giving an increased height of 3 feet.

At Fulton, Tenn., with 600,000 cubic feet to be added, the increased stage would have been 10 feet.

At Helena, 360,000 cubic feet would have been added, giving an increased stage of 4 feet.

At Hays Landing (or Lake Providence), the discharge of 1,000,000 cubic feet would have been doubled, or made 2,000,000, with an increase of stage of 10 feet. (I think this too small an estimate by several feet).

At Red River Landing, there was 1,600,000 cubic feet passing in the main channel, 300,000 passing in the Atchafalaya, and 300,000 more passing overland. If this amount of overflow water were proportionately divided between the Mississippi and Atchafalaya, it would raise both streams by at least 3 feet.

At New Orleans, the computed maximum discharge for 1882 was 900,000 cubic feet. Since the maximum discharge in the channel at Red River was observed to be 1,600,000 cubic feet per second, there must have escaped from the channel between these points as much as 700,000 cubic feet per second at the top of the flood. If now 300,000 cubic feet more had been added to the channel discharge at Red River, and all remained confined from there to the Gulf, it would have *doubled the discharge of*

the river at New Orleans. As it was, the water overtopped the levees in many places, and many breaks were formed until sufficient relief was found to enable the levees to hold the balance. In order to double the discharge at New Orleans, the increased stage would have been at least 10 feet. (Gen. Comstock does not estimate the increased stages at Red River and New Orleans, but the figures on which these estimates are based, are all found in the report.)

The fact is, the mouth of Red River is properly the head of the delta, and has been for ages, so that the river at New Orleans never has had to carry more than 1,000,000 cubic feet, the balance having been always lost out over the banks and through natural outlets above. For us now to demand that this channel which overflows with 1,000,000 cubic feet, shall suddenly be called upon to transport 2,000,000, is like passing a legal enactment that a quart measure shall hold two quarts of water.

There are some natural limitations to engineers' as well as legislators' demands. We now see how it is that the concentration theory, carried out to this extent, means levees of ruinous cost, or else the utter destruction of agriculture on the upper and lower coast, and the actual submergance of New Orleans. And yet Captain Eads resigned his position on the commission because they declined to close up the Atchafalaya entirely, and so precipitate 300,000 cubic feet more than we have here assumed upon this already suffering region. Even Achilles had his vulnerable point.

Since the increments of stage above predicted are all above the high-water marks of 1882, and since this high water generally overtopped all levees then built, it becomes a sufficiently alarming subject of inquiry. The practice of local and State authorities, wherever levees have been built on the Mississippi River, has been to build them about a foot above the highest known high-water marks, on the assumption that when the river was fully confined to the channel, the stage would be no higher than when allowed to spread over and discharge through a swamp 50 miles wide. This method of reasoning was well enough when but small patches were to be leveed in here and there, but when the whole of any one of these great swamp basins is shut off, and the waters find no escape except down the channel itself, it should not be surprising that it should require a greater stage whereby to discharge the greater amount.

It is rather refreshing, therefore, to see that this very plain argument in favor of a higher flood stage for a confined channel nowhere receives so little credence as among these improvident sufferers, who, after 50 years of trial, have never yet built a levee high enough to keep a large flood out of any one of their great swamp basins.

Taking the estimates for increased height due to confining all the flood waters by levees as above given, and allowing a foot or two for top of levee above high-water marks, we may say that such levees must average at least eight feet higher than those now built. In other words, all levees now built must be increased, on the average, to double their present height, and where there are now no levees they must be built to these enormous proportions.

The cost of a levee 16 feet high, 8 feet wide on top, and with slopes 3 and 4 to 1, as is recommended by the commission, allowing 25 cents per

cubic yard, is about $50,000 per mile. which means a total additional expenditure of about *fifty million dollars* to confine such a flood as that of 1882 to the channel from Cairo to the Gulf, allowing also the Atchafalaya to discharge its full capacity.

The river commission have estimated eleven million dollars as sufficient for this purpose, basing this estimate on a height of levee 2 to 3 feet above the flood of 1882 as being sufficient to prevent all overflow. This low estimate is the occasion of Gen. Comstock's exceptions. In this estimate they agree, however. with the residents of these regions, whose continued faith in levees that have always failed them is something phenomenal. If eleven million dollars would really keep the river within bounds below Cairo, perhaps it would be wise for the States interested, simply as a profitable investment, to make the outlay. But if complete protection would cost fifty millions, it is very doubtful if it would pay a fair dividend. For the general Government to build these levees, let the cost be what it may, would, in my judgment, be a great blunder. It would result in great injury, rather than benefit, to low-water navigation, and the benefits, such as they are, would accrue to the riparian owners, being private instead of public in their nature.

If the general Government must go into the business of improving swamp lands, let it improve its own rather than those it has long since disposed of in a fair bargain.

The incalculable damage, also, in destruction of life and property, in case a break should occur in one of these high levees, being in many places 25 feet high, with a thickly-settled population behind it, should make one slow to put in jeopardy such great interests by making them depend on such frail and treacherous barriers.

The second method of treatment, therefore, is hardly feasible on account of its great cost, and because of its injurious effects upon low-water navigation.

We come now to the *third method*, which I shall offer as being more efficient and less expensive than the *first*, and as being less expensive, involving no risk and less injurious to navigation than the *second method*.

The characteristic features of this system are:

1. Moderate-sized levees, or such as will keep out all moderate or ordinary floods, or such levees as are now found along the lower parts of the river.

2. Provision made for the discharge over these levees of the excess over the channel's capacity, in case of high floods, without injury to the levee.

3. Provision made for the conveyance of this flood overflow back from the river bank to the main drainage channels of the bottoms, with a minimum of injury from flooding the lands.

Whether levees be beneficial or injurious to low-water navigation, evidently their effect is less as their height is lower. The water is not usually over the top of the bank more than a month or two at a time, so the effect is correspondingly limited. Again, as the great variation in width becomes gradually reduced by means of the low-water works adopted by the commission, the injurious effects claimed for the levees, n the way of bar formation, will be diminished, and finally, for a regu-

lated channel, their effect will become very small. In view of all these arguments, I think the opponents to levees would consent to a compromise, and be willing to allow a small injury to navigation in consideration of great benefits to be gained for the inhabitants of the bottoms.

Levees of this moderate size would keep out all ordinary floods that rise to a few feet over the banks, and so furnish complete protection against the regular annual freshets. They would probably be sufficient to confine the flood waters four years out of five. The floods of the last three years would all have gone over them. The trouble now comes with these exceptional floods. How shall we pass this excess of water from Cairo to the Gulf without its tearing to pieces these moderate-sized levees, which for four-fifths of the time are sufficient for complete protection? I answer that some artificial means must be provided to allow their excess to escape across the line of the levee without doing damage This can only be done by arranging weirs for this escape, with revetted slopes, at such points on the line of the levee as will best relieve the river, and also where there are the best facilities for carrying off the flood water.

This is not an untried remedy. On the River Loire, in France, these weirs have been introduced to prevent the building of levees of extravagant height, and they have proved very efficient and satisfactory. On the Mississippi the great argument against them is that of cost, owing to the length to which they must be carried. Thus, for a depth of 2 feet on the crest of one of these weirs, we would have a discharge of about 10 cubic feet per second per lineal foot of weir. To discharge 100,000 cubic feet per second, therefore, would require 10,000 lineal feet of weir. If a 3 foot overflow be allowed, there would be needed only 5,800 lineal feet of weir to discharge 100,000 cubic feet per second, or to discharge one million cubic feet it would require 11 miles of weir with a 3-foot depth on crest. In order to obtain this depth on the crest, the weir should be some four feet below the top of the levee, and so freely exposed to the channel that little slope is required to bring the water from the channel to the weir. These weirs must then be distributed in such a manner that the water, after passing them, may be most readily carried off to the distant low portions, where part of it remains impounded, as now, in every great flood, and the balance escapes down the natural channels to the outlet of the basin. On all the great swamp fronts, there are many such favorable sites. As above noted, before levees were built, there were many natural outlets from the river to the swamps, and these could still be utilized and weirs placed so as to discharge into them. A striking example of this is what is known as Yazoo Pass—now generally called Grant's Pass—being a large bayou opening out from the main river some fifteen miles below the mouth of the St. Francis, and discharging into the Cold Water and finally into the Yazoo River. This bayou is so large that General Grant cut the levee in 1862 which closes its connection with the Mississippi, and took his whole fleet of gunboats and transports down through it, intending to reach the high ground in the rear of Vicksburg by this route, which he probably would have succeeded in doing had he not become alarmed at the reported decline of the river, which threatened to leave him stranded

before he could work his way through the impediments with which the enemy obstructed his passage. The most favorable distribution of these weirs and the amounts to be discharged over each could only be determined after more elaborate surveys than have yet been made. The discharging capacity of these small water-courses is now very much lessened and in many cases almost entirely destroyed by "rack-heaps," or "rafts" of stranded drift-wood, sometimes of miles in extent. If these were cleaned out and kept out, the stream would continue to increase its discharging capacity just as the Atchafalaya has done. There would be great trouble also in keeping the weirs free from drift. This possibly might be done by rows of piles in front of the weirs to intercept the drift, but these would have to be cleared frequently, or the accumulation would wholly cut off the weir from the channel. The arrangement of the details of this method could only be made after an elaborate study of the local conditions in each case, aided by extensive surveys of the region. My knowledge of the conditions found in these swamp basins as obtained in several years' engineering experience over a large portion of the distance from Cairo to Red River, especially my high-water observations in the flood of 1882, leads me to believe that the natural drainage of these basins could have been so improved as to have discharged all the overflow waters of that year with little damage from flooding cultivated lands, if the overflow could have been properly distributed as is here proposed by the weir system. These regions are cut up by innumerable bayous, running parallel to and away from the river, which could readily discharge the greatest overflow if they were properly cleared of all obstructions. As compared to these many cleared channels the discharging capacity of tangled forests and cane-brakes is almost zero, so that now, when there is a break in the levee, perhaps in the most unfavorable place for carrying off the waters, it overflows, in one common inland sea, forest, cane-brake and plantation alike, and must slowly and laboriously find its way through these obstructions as best it may. The result is a stage of water behind the levees about equal to that in front of them. By the weir system, then, there would be much less water impounded in the swamps, and therefore the swamp discharges at Helena and Vicksburg would be much more prompt than now. But since other weirs are to be provided on the opposite side of the river, in each case, to take this surplus at once off into other channels, no great injury need be feared from this sudden return of the swamp overflow. This rapid discharge through the swamp is essential to a low stage of flood waters over these areas.

We can now revert to our original statement, that perhaps not more than one half the area of these basins would probably ever come under cultivation, and we see what the other half is used for. The lower one-half is sacrificed that the upper or higher half may be utilized.

In comparing this system with the first, or that now in use, the cost of levee renewal, caused by breaks whenever the river overflows them, added to the damage done by the overflow, must be compared with the interest on the additional capital necessary to build the weirs and clean out these channels, to which must be added the cost of keeping the weirs in repair and the channels cleaned out.

If thought advisable, some provision might be made to keep the weirs closed, up to the tops of the levees, when there was reason to believe the flood would not reach so high a stage. The discharge over the weirs could then be under control, and as much water let out as desired.

It has been often asserted that the overflow that goes into the St. Francis swamp need not be returned to the channel again, but can be conducted by an auxiliary channel on the west bank directly to the Gulf. Such arguments are usually advanced by persons wholly unacquainted with the topography of the region. There is a spur from the Ozark Mountains, called Crowley's Ridge, which extends to the Mississippi River bank at Helena. This ridge limits the St. Francis swamp on the west and turns all its overflow waters back into the river. It is quite impracticable to carry a large river either over, under or through this ridge, so the scheme is a very visionary one.

In the method above outlined the course of the flood waters would be such as nature has provided, and such as every great flood has taken for thousands of years. It simply removes the obstacles to the rapid discharge of the overflow water and puts this overflow where the facilities of discharge are the greatest, and also allows to escape from the channel the minimum amount consistent with safety to the levees themselves. It seems to me to be worthy of a careful study, as furnishing to the swamp region a very fair degree of protection at a minimum expense, and at the same time being fairly free from the charge of injuring low-water navigation.

For such additional study I would respectfully recommend it, and it is only with a sincere desire to aid in solving one of the most perplexing problems connected with the improvement of the Mississippi River that I have offered these suggestions.

PROBLEM IN CURVES.

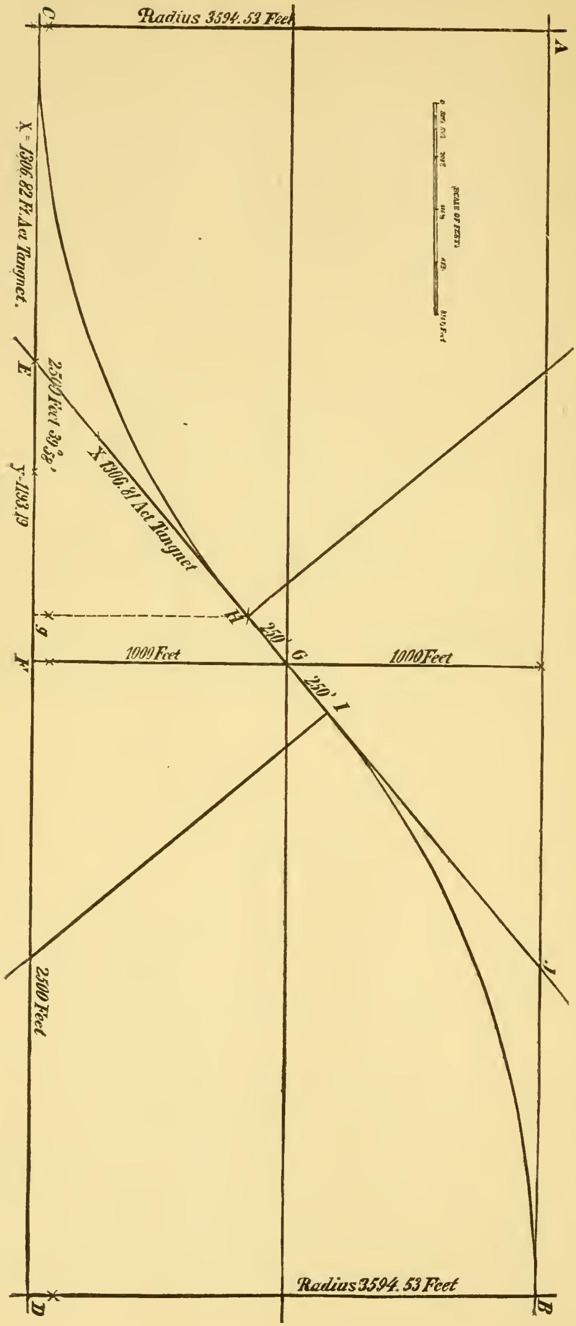
By Augustine W. Wright, Member of the Western Society of Engineers.

[Read May 6, 1884.]

Your Committee on Railroads, etc., noticed a communication to the *Railroad Gazette* in its issue of April 18, 1884, asking a solution of the following problem. No answer having so far appeared in the *Gazette*, your Committee has considered the matter of sufficient interest to members of this Society for it to have prepared the following:

"Given, two parallel lines 2,000 feet apart, it is required to connect these lines by two curves of equal radius in opposite directions and having a tangent 500 feet long between them. The length of this connection measured on one of the parallel lines is to be 5,000 feet."

Referring to the accompanying sketch, let A B and C D represent the two parallel lines required to be so connected. By construction they are 2,000 feet apart. The reversing point of reverse curves between parallel tangents is in the line joining the tangents, and the above problem requires that each curve should end 250 feet from a point at the centre of the said rectangle. Let x = the actual tangent of the required curves, the distance on plan from C to E or E to H.


Radius 3594.53 Feet
C
A
X = 1306.82 Ft. Act Tangnet.
E
2500 Feet 30° 58'
Y-1193.19
X 1306.81 Act Tangnet
H
250'
G
250'
I
g
F
1000 Feet
1000 Feet
J
2500 Feet
Radius 3594.53 Feet
D
B

Let y = the distance from point of intersection of the tangents to a point half the distance along the parallel lines, as E to F.

From F to G will be one-half of 2,000 feet, or 1,000 feet by construction. From C to F will be one-half of 5,000 feet, or 2,500 feet by construction.

Therefore $x + y = 2{,}500$.

$(x + 250)^2 = y^2 + 1{,}000^2$.

Substituting and reducing we find $x = 1{,}306.81$. The actual tangent of required curves, $2{,}500 - 1{,}306.81 = 1{,}193.19$ or y, the distance from E to F. $\frac{1{,}000}{1{,}193.19} = .83808$, the tangent of the angle of intersection. From a table of tangents we find this to be the tangent of an angle of 39° 58′. 50 times the tangent of ½ angle of intersection divided by the actual tangent = sine of deflection angle. $\frac{50 \times .36364}{1{,}306.81} = .01391$. From a table of sines we find this is an angle of 48 minutes, and the curves are 1° 36′. Fifty divided by the sine of the deflection angle = Radius $\frac{50}{.01391} =$ 3594.53. In running these curves upon the ground your Committee would measure 1,306.81 feet from the starting point of one curve along one of the parallel tangents and drive a hub, and mark the point with a tack, say at E. Then set the transit over this point. Sight along the tangent and turn the angle of intersection as above found. Measure along this line 1,306.81 feet and put in hub and tack. This is the end of one curve or H. Measure along the same line 500 feet more, and put in hub and tack. This is point I of reverse curve. Continue this line to point of intersection J, which should be 1,306.81 feet, and put in hub and tack. Measure along the last tangent 1,306.81 feet and put in hub and centre. This should correspond with one of the points given by construction B. Your Committee always prefers to line in the ends of curves from the tangents, as there is less probability of errors. Taking the transit to the beginning of either curve, and sighting along the said tangent, your Committee would proceed to put in the curve stakes as required.

Respectfully submitted for the Committee.

COMBINED SEWERS VERSUS THE WARING SYSTEM—A REJOINDER.

By Robt. Moore, Member of the Engineers' Club of St. Louis and M. Am. Soc. C. E.

[Read May 7, 1884].

The reply of Mr. Chanute * to my criticism of his lecture on the sewerage of Kansas City presents several points which call perhaps for a few further words from me in order that the facts and my own position in regard to them may not be misunderstood.

First of all, I would remark that the differences between us grow very largely out of the different stress which in our plans we lay upon the needs of the future as compared with those of the present. Mr. Chanute is much more concerned about the needs and the payments of to-day than

* See Journal for March and April.

about those which will come hereafter. "After us the deluge," would seem to be his motto. In making plans, however, it seems to me, and I think to engineers and prudent men generally, that the future should have greater weight than the present, and particularly in planning works of sewerage. For, if properly built, sewers are the most permanent of all public works. The City of Rome is drained to day, in part, by sewers built 2,500 years ago. Then, too, mistakes in works of this kind are extremely difficult to rectify. To replace a badly built or insufficient sewer is a work of much greater difficulty than if the first had never been built.

If Kansas City were destined to remain just as it is to-day I should very freely admit that a complete system of storm-water sewers, though desirable, was not necessary, and that its construction would be unwise. I should further admit that for a considerable part of the city the proper course would be to build sewers for house drainage only, though I should not exclude from them all rainwater, and should not build them under the Waring patents. For still other large parts of the city to which no water pipe has been extended, I should not recommend the present construction of any sewers at all, but should say that a system of earth closets was cheapest and best.

But nothing is more certain than that the city will not remain as it is to-day. It is growing faster, perhaps, than any city in the West, and gives certain promise of becoming the most important commercial center in the whole Missouri Valley. Already it has long lines of business houses that would do credit to our oldest cities, and its streets are thronged with a traffic which only the most substantial block pavements will endure. So that whilst Mr. Chanute can, as he gives us to understand, bear now with great equanimity the rush of storm-water past his property (which by the way is unoccupied except by a ruined house and some stables) to cut out deep gulches in the property of his "brick-making neighbors," it is not safe to assume that his neighbors, or his own successors, will long be thus patient. On the contrary, we may with confidence assume that in the future, and probably in the very near future, the storm-water will become there the same nuisance that it is in other large cities, and the same means be demanded for its removal.

Of this future demand for storm-water sewers Mr. Chanute thinks but lightly, and claims that I have greatly exaggerated its importance, and this notwithstanding the fact that its reality and urgency are confirmed by the experience of the vast majority of large cities both in this country and in Europe, as well as by a multitude of facts which occur daily under our own eyes. In support of his view of the matter he refers to the city of Baltimore, with a population of 322,000 and only eleven miles of storm sewers, but where, he says, the citizens prefer to have the streets swept by the storm-water, and where in consequence they are "notoriously clean."

Now, even granting that these statements could be taken without any abatement, they could not outweigh the great mass of testimony on the other side. But an examination of the reports of the city officers of Baltimore fails to confirm Mr. Chanute's view of the facts. Judging from

this evidence Baltimore is so far from being a model for other cities in this or any other sanitary aspect as to be rather a most excellent example of things to be avoided. In few cities have obsolete methods a stronger foothold. Thus the Mayor [Report for 1880], when speaking of the cobble-stone pavements with which their streets are mainly covered, and which he denounces as the poorest of the kind, says they are "a characteristic evidence of our reverence for relics of the past." The soil of the city is honeycombed by 80,000 cesspools, whose evils are intensified by an abundant water supply, and of the few sewers which they have, a considerable part hardly deserve the name. For they are simply old streams arched over by the owners of the land through which they ran, according to their own judgment and convenience, without any regard to alignment or grade, or the needs of other parts of the city. They are in fact private property, and not controlled by the city either for cleaning or repairs. As for the streets, the storm-water fills them in many places from curb to curb, cleaning them it may be, but rendering them for the time impassable and causing serious damage, of which instances could be cited from every year's reports.

In 1879, for example, the City Commissioner urges the building of a sewer in North avenue "to carry off the surface-water which has been so destructive along its bed during heavy rains." The next year's report speaks of the accumulation of storm-water at another point as "one of the greatest nuisances in the city," and the Mayor recommends an expenditure of $300,000 for its abatement. And in 1881 the Health Commissioner sums up the facts in regard to the condition of the streets in these words: "A great defect in our streets is the surface drainage. House-sweepings, kitchen refuse, slops, etc., find their way into open gutters, pools of water collect at depressed points, giving rise to miasms and odors that are anything but conducive to health during hot weather, and in winter time invade the adjoining pavements by extension of layers forming broad sheets of ice dangerous to life and limb. All of this nuisance can be obviated and the streets kept dry and free from offensive and pestilential odors and sidewalks free from ice by a proper system of sewerage"—a picture in which we cannot discern either the "notoriously clean" streets or the contentment of the citizens.

Another point much insisted upon by Mr. Chanute in his reply is that what I say in regard to the cost of sewerage is unsupported by estimates and figures, and he then gives a number of figures which show, what I had no thought of denying, that the Waring system by itself will cost less than the combined system. The only statement in regard to cost made in my paper was to the effect that the combined system plus the house-drainage system would cost more than the combined system alone—a statement which, I submit, does not need to be supported by anything, and which my critic himself will not, I think, deny. What he does claim is not a contradiction of this statement but a modification of it, viz.: that by methods of economy which he indicates the full cost of a double system need not be incurred.

The first of these economies is that he would place the storm-sewers much nearer the surface than is practicable where they are used for the

drainage of houses. But in regard to this the fact is that in very many cases, perhaps the majority, the grades and depths of sewers are determined not by the requirements of the house drainage, but by the necessity of draining some low point at the upper end. In the deepest sewers this is always the governing consideration. But even where the depth is not fixed in this way, the amount that can be saved by putting sewers nearer the surface is not very great. Part of the excavation may be saved, but the cost of masonry, removal of surplus earth, inlets, superintendence and engineering will be unchanged. To test the matter, I have with the aid of Mr. William Wise, Assistant Sewer Commissioner, whose knowledge of everything pertaining to the art of sewers is unsurpassed, computed for two typical cases in St. Louis, and at actual contract prices, the amount that would be saved by carrying the excavation to a depth of six feet instead of twelve, and find it to be one-twelfth of the whole cost, and this without taking into account the cost of engineering and superintendence. As on many sewers, for the reason already given, no reduction at all can be made, the amount that could be saved in this manner on the whole system of storm-sewers will not exceed five per cent. Taking Mr. Chanute's figures for the cost of combined sewers in Kansas City, viz.: $20,727 per mile (although one third of the whole mileage was built in 1883 at a cost of only $18,273 per mile, or nearly $2,500 less than his figures), this saving would amount to $1,036, and would bring the cost of storm sewers such as he proposes down to about $19,700 per mile. This, added to the cost of sewers for house drainage, as per his estimate, $10,000 per mile, would give a total of $29,700 per mile, as against $20,727 actually spent.

And this brings us to the chief economy which he proposes, which is that a large part of the storm sewers shall be omitted altogether. On this point, however, it should be borne in mind that the part of the system that will be retained will, with rare exceptions, be the lower end, where the volume of water and the consequent nuisance are greatest, and where also the cost of the sewers is a maximum; whilst the part omitted will be the upper end, where the difference in the cost of the two classes of sewers becomes rapidly less and less, until at the summit it is finally nothing.* So that by this method we can only save where the saving is of least value.

For the sake of a more exact comparison of the two plans let us take Mr. Chanute's figures of cost with the deduction therefrom already given, and let us further assume that to complete either system will require 100 miles of sewers. Our data will then be as follows:

	Per mile.
Average Cost of Waring sewers	$10,000
" " combined "	20,727
" " shallow storm sewers	19,700
Cost of shallow storm sewers at summit	10,000
" " " " " lower end	29,400

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* Thus the sewer whose average cost we have found to be $19,700 per mile, will at the summit cost at the rate of $10,000, and at the lower end at the rate of $29,400 per mile. The average cost of the lower half will be $24,550, and of the upper half $14,850.

From these we obtain :

1. Cost of combined system:
   100 miles @ $20,727 per mile $2,072,700
2. Cost of a double system, with Waring system complete and storm system half complete:
   100 miles Waring sewers @ $10,000 per mile 1,000,000
   50 " shallow storm sewers @ $24,550 per mile 1,227,500

   Total $2,227,500

Or about 15½ per cent. more than the cost of the combined system. Carrying the figures still further, we shall find that a complete Waring system and forty-two and one-half miles of shallow storm sewers will cost the same as a complete system of combined sewers.* That is to say, for the same expenditure we should in the one case have a single system of sewers and complete removal of both house drainage and storm water, and in the other a complicated double system and nearly sixty per cent. of the storm water still unprovided for except by open gutters. Unless, therefore, there be some marked sanitary advantage in the double system. there can be no question as to which plan is the better investment of the money.

Coming, then, to the sanitary question, Mr. Chanute makes the remark that I seem to have "quietly ignored all that has been said on the subject by sanitarians both in this country and in Europe," and this notwithstanding my general statement that the combined system is indorsed as promoting the public health by the ablest and most experienced sanitarians and engineers in the world, and a detailed statement of the testimony of the Chief Medical Officer of the English Local Government Board to the effect that the air from small sewers is more dangerous than from large ones. Mr. Chanute then quotes at length, as if from a most conclusive sanitary authority, from a report on methods of sewerage made to the New York State Board of Health by Mr. James T. Gardner of the State Topographical Survey. In this report the author states, with many italics as if he were announcing some great discovery, that the evil effects of sewer air are due not to sewer gas, for no such gas exists, but to bacteria ; that "ideal hot-beds" for the production of these "fatal organic germs" are found in the walls of large sewers, the air from which is "still deadly," notwithstanding "every engineering device has been exhausted to keep them clean and well ventilated." Without further ado, therefore, he pronounces the combined system of sewerage to be from a sanitary point of view a failure, and then goes on at much length to set forth the surpassing merits of the "American plan," designed by Col. George E. Waring, Jr.

Now, before allowing ourselves to be greatly disturbed by these rather startling statements, it will be well to look somewhat into the proofs upon which they rest, Mr. Gardner not having taken the trouble to give them to us. Doing this, we find first of all that the researches of Pasteur, Koch, Cohn, and Tyndall, to whom a greater part of what is known

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* The exact figures are as follows :

100 miles Waring sewers @ $10.000 .... $1,000,000
42½ miles storm sewers @ $25,277.50 1,074,294

Total $2,074,294

on this subject is due, have shown beyond a doubt that bacteria, the "fatal organic germs" of which Mr. Gardner speaks, are of many species, differing widely in their characteristics and conditions of growth, and that the vast majority of them are entirely harmless to animal life. The bacteria which produce ordinary fermentation and putrefaction may be breathed, or even introduced into the blood, with entire impunity.* The presence of other species in the digestive tract is normal, and perhaps even necessary to its proper functions.† Disease-producing bacteria are the exception, not the rule, and that these kinds are specially produced on the walls of large sewers is absolutely without proof. The "hot-beds" of which Mr. Gardner speaks are indeed well characterized as "ideal."

Some extended and careful observation on this subject by M. Miguel recently published,‡ show that whilst the air of an ordinary Paris bedroom, regarded as clean enough, contained a mean of 5,260 organic germs per cubic meter, the air of the sewers contain only from 800 to 900, or about one-sixth of the former number. These experiments are related with the further remark that in the sewers the germs were the bacteria proper, but that when inoculated in animals they were without effect—though according to Mr. Gardner the effect should have been "deadly." To the same purport are the well-established facts that the health of sewer-cleaners, a great part of whose lives is spent in the air of large sewers, is as good as that of other laborers; that the construction of such sewers in cities has always been followed by a marked decrease in the death rate, and that the best sanitary record is found in towns sewered on the combined system. On this latter point the testimony of Dr. Buchanan, given in my former paper, who cites no less than six towns sewered on the separate system, is very conclusive.

To Mr. Buchanan's testimony, however, Mr. Chanute objects that the experience of Croyden and the other towns mentioned is not in point as against the Waring system, for the reason that in none of them was any use made of the automatic flush tanks which characterize that system, although it was shown that the sewers were flushed by other means. In other words, the superiority claimed does not belong to the separate system generally, but only to that particular form of it which has been patented by Col. Waring. With the field of discussion limited in this way, the only experience available to test the Waring system is that of Memphis, this being the only town sewered on this plan of which we have the sanitary record. But here, as I have already shown, the death-rate since the construction of the Waring sewers is 36 per 1,000 as compared with 34 in the preceding five years in Memphis, after excluding deaths from yellow fever, and 21 in the last four years in St. Louis.

To these figures my opponent objects, first, that the deaths from yellow fever in Memphis prior to 1880 should not have been omitted, and that the exemption from the fever since then should be credited to the new

* See Gradle on Bacteria, p. 79.

† See Gradle on Bacteria, p. 76.

‡ "Les Organismes de l'Atmosphère." Par M. P. Miguel, chef du service micrographique a l'observatoire de Montsouris. Paris, 1883.

Reviewed in Science, Vol. III., p. 518.

sewers. In reply to which I ask, To what, then, shall we credit the like exemptions in New Orleans, and Grenada, and Shreveport, and Mobile, in none of which is there the Waring or any other system of sewers, and all of which have had epidemics of yellow fever? As I remarked in my first paper, the yellow fever has not only not visited Memphis since 1880, but it has not visited any other place within three hundred miles of Memphis, and surely it is not claimed that the Waring sewers have protected this whole region. In all these cases the fever has been kept out by quarantine, and I excluded it from the Memphis death rate for the same reason that I excluded cholera from the death rate in St. Louis prior to the construction of sewers there, viz.: that in each case the epidemic was due to causes with which the presence or absence of sewers had nothing whatever to do.

Mr. Chanute further objects that the death-rate in Memphis since the sewers were built is less than I have stated it, and that my figures of population do not agree with those used by the President of the Memphis Board of Health, Dr. G. B. Thornton. Dr. Thornton, however, makes no higher claims for his figures than that they are estimates based upon the city Directory, and does not profess to be satisfied with them himself.* How utterly delusive such estimates are, none know better than the people of St. Louis, whose health officers in 1877, upon the same kind of evidence, claimed a population of 500,000 and a death-rate of 10.88 per 1.000, although the utmost diligence of the Census officers three years later could find only 350,520. The real number in 1877 could not have exceeded 312,000, or only $62\frac{1}{2}$ per cent. of the number claimed. A smaller correction than this applied to Dr. Thornton's figures will bring them down to those used by me, which are based upon the United States Census of 1880, with an assumed rate of increase for subsequent years of four per cent. per annum.

That this rate is not an absurd one, as Mr. Chanute appears to think, is shown by the fact that the average annual rate of increase since 1870 of all cities in the United States which in 1880 had a population of 50,000 or over, was only $3\frac{6}{10}$ per cent., the rate for Southern cities being considerably less. In Baltimore, for example, it was $2\frac{2}{10}$, in Washington $3\frac{1}{10}$, in Richmond $2\frac{4}{10}$, in Louisville $2\frac{1}{10}$, and in New Orleans least of all, being but $1\frac{2}{10}$. The highest rate shown by any city in the whole list is $6\frac{2}{10}$ per cent., by the city of Pittsburgh. Desiring to be liberal, and wishing to compare the figures for Memphis with those for St. Louis, I used the same rate as for the latter city, viz., four per cent. To bring the death rate in Memphis since the construction of sewers down to what it was before, would, as stated in the note to my former paper, require us to assume an annual rate of increase in the population of eight per cent., or one-third more than the maximum rate already mentioned, which,

*The figures used by him in his reports since 1880 are these:

			Increase over preceding year.
1880.	U. S. Census	33,593	
1881.	Estimate from Directory	40,000	19.06 per cent.
1882.	" " "	46,014	15.03 " "
1883.	" " "	62,335	35.47 " "

These figures show rates of increase so enormous and so irregular as to make them, in the absence of an official census, wholly incredible.

though not in the nature of things an impossibility, is an assumption not to be entertained upon any evidence less than an actual official count.

Nor will it do to take out the strangers and non-residents who have died in Memphis during the last three years, as Dr. Thornton would have us do, unless we also take them out for former years, in which they no doubt bore just as large a proportion to the whole as they have done since.

So that all the facts in our possession point to the conclusion that in the only city of any importance to which the Waring system has been applied, the death rate has increased rather than diminished, and is 70 per cent. greater than in St. Louis, which has been sewered on the combined system. And for the present the alleged sanitary superiority of the patented system of sewerage rests, as is the case with many other patented systems, upon no better authority than the opinions and assertions of its advocates. And if further experience should show this method of sewerage to be positively unsafe, it need not greatly surprise us. For there is one feature of the Memphis work which, it will be remembered, is condemned by the great majority of sanitarians as involving very serious dangers, and that is the untrapped and unflushed house-drains. Whilst these remain unchanged the flushing of the main sewers very many of which probably do not need flushing, is of small consequence; and it may well happen, as has happened in other like cases, that the sewers shall be a means of spreading disease rather than arresting it.

But whilst this feature is a characteristic of the Waring system and covered by one of the claims of his patent, it is no part of the separate system, which with proper precautions may be made just as safe as any other. And where the sewerage needs to be disposed of by special means, such as pumping or irrigation, or where the cost of the combined system is too great, as in small towns and scattered villages, the separate system is the proper one to be adopted. But where, as in the particular case under discussion, the question of disposal does not enter, and where the cost is to be borne by a large and prosperous community, the combined system best solves the problem of drainage and brings the largest return for the money spent.

TUNNEL ALIGNMENT.

By F. P. Stearns, Member of the Boston Society of Civil Engineers.

[Read May 21, 1883.]

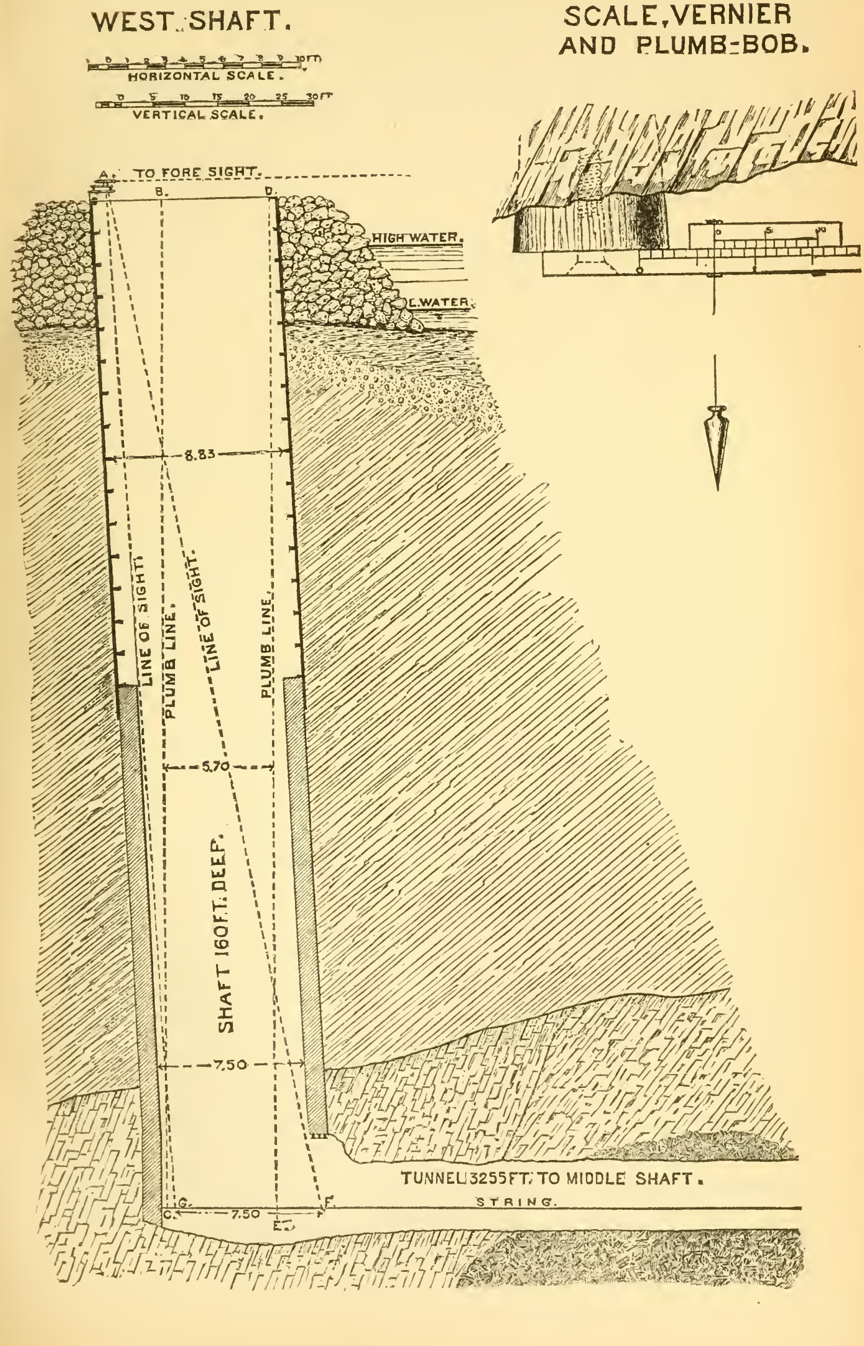
The basis of this article is the work done at the Dorchester-Bay Tunnel on the line of the new Main Drainage Works of Boston. Some problems in tunnel alignment arose there, which could not well be solved by the methods generally used.

The main portion of the tunnel was straight, 6,090 ft. in length, nearly level, and about 150 ft. below high tide in the bay.

There were three shafts known as the West, Middle and East shafts; the East and West shafts being at the ends of the length referred to, and the middle one somewhat east of the middle, or, more exactly, 3,255 ft. from the West one.

The three shafts, although of the same design, did not, as the work was

DIAGRAM ILLUSTRATING ALIGNMENT OF DORCHESTER BAY TUNNEL, BOSTON, MASS.



executed, present equal facilities for transferring lines down them, nor were exactly the same methods used at the different ones. To avoid repetition and length, however, this article will refer only to the work done at the West shaft, this shaft being chosen because it presented peculiar difficulty in the use of the common method of alignment by means of plumb-bobs suspended from the top, and because the work was done at a later date than at the other shafts and the method used was more nearly perfected.

A vertical section of the west shaft, on the centre line of the tunnel, as it existed at the time the lines were run, is shown on the accompanying diagram (page 191).

The shaft was out of plumb in the line of the tunnel 2.66 feet in its depth of about 160 feet. The upper half was formed by sinking an iron cylinder having an internal diameter of 9 feet 6 inches, which was diminished at the flanges where the different sections were bolted together to a clear opening of 8 feet 10 inches. Below the cylinder the shaft was sunk for the greater part of the way through clay and was lined with timber. Below the timbering the shaft was in rock.* At the date represented by the diagram the shaft had been lined with brick-work, having an internal diameter of 7½ feet, from its bottom to a point about 5 feet above the bottom of the cylinder. The shaft contained six lines of steam, water and exhaust pipes, and the guides for the "cage." None of these came on the centre line. The lines *B C* and *D E* represent plumb lines from the top to the bottom of the shaft, placed as far apart as possible. The distance between them was 5.7 feet. This would have furnished a very short base from which to extend a long tunnel line, but the shortness of the base was not the greatest difficulty. In shafts of the depth of this one, where water is dripping and where currents of air are produced by hot steam-pipes and by occasional leakages of steam from them, it is necessary to protect the plumb lines by some kind of tubes; but any permanent tubes for this purpose would have been out of question in this shaft, as they would have been directly in the path of the cage on which all material was transported.

In view of the difficulty of using plumb-bobs Mr. G. H. Crafts, the assistant-engineer then in charge, concluded that much more satisfactory results would be obtained by sighting down the shaft with a transit; and he proceeded to design the necessary instruments and to have them constructed.

INSTRUMENTS AND METHODS.—The top instrument was a large "straight-line" transit having a telescope magnifying forty diameters, with an object glass two inches in diameter. The standard which supported the telescope was U-shaped in plan, the wyes being near the ends of the U, so that the telescope could be used to sight vertically downward, as well as horizontally.

This standard was supported by three levelling screws, which rested upon the U-shaped top of a casting. The casting was about 2 feet 6 inches high, and was made to be bolted to the top flange of the cyl-

* A description of difficulties encountered while sinking this shaft is given in Shaft Sinking under Difficulties at Dorchester-Bay Tunnel, by D. McN. Stauffer. Trans Am. Soc. of Civil Engineers; October, 1881.

inder. A striding-level was used to determine when the axis of the telescope was horizontal.

The position of this instrument at the top of the West shaft is shown at A on the diagram, and the lines of sight down the shaft by the lines *A C* and *A F*. The distance between the lines at the bottom of the shaft was 7.5 feet.

At the bottom of the shaft a string was stretched along the centre line of the tunnel from the west side of the shaft to a point about 100 feet into the tunnel. The end at the shaft was fastened to the zero notch of a vernier sliding on a brass scale graduated to hundredths of a foot and reading by the vernier to thousandths. Ninety-three feet from this scale and nearly level with it a bolt was set in the side of the tunnel from which offsets were taken to the string. These offsets were taken with a brass rod fixed horizontally, perpendicular to the line of the tunnel, and graduated in the same manner as the scale. The string was so fastened in the tunnel that, where it passed the rod, it just touched its upper surface.

To furnish the necessary illumination at the bottom of the shaft a large lantern with a 12-inch reflector was used. This lantern threw its rays horizontally, and a mirror set at an angle of 45 degrees deflected them up the shaft, thus furnishing a brilliant spot at the bottom of the shaft on which were seen as black lines both the string and the cross-wires. As the use of a vertical cross-wire would not have admitted of accurate sights, and would have caused confusion on account of its looking so much like the string, two wires crossing each other and making a small angle with the vertical were used instead.

After setting the telescope on the tunnel line above ground it was revolved and pointed at the string close by the scale, and this part of the string was set on line in accordance with orders received by telephone from above. It is, perhaps, needless to add that the end of the string in the tunnel was held "on line" during this operation as nearly as the existing knowledge permitted. The telescope was next directed to the string at the opposite side of the shaft, and that part was put on line by moving the string at the offset rod in the tunnel. These operations were repeated many times in a day, and each trial gave a line in the tunnel fixed by two points at a considerable distance from each other.

The only important error which was feared was that which might be due to refraction in the shaft, caused by the warmth of steam-pipes on one side. Such a cause of error would not affect the results by the whole amount of the refraction, but rather by the difference in the refraction of the two lines of sight down the shaft.

At the West shaft the line was transferred into the tunnel on three different days with the following results, as compared with the line found to be the true one after the completion of the excavation :

Date.	Variations from true line per 100 feet.	Variation from true line in width of shaft.
May 22, 1881	0.0085 feet North.	0.0006 feet North.
June 5, "	0.0193 " "	0.0014 " "
July 10, "	0 0044 " "	0.0003 " "
Average	0.0107 feet North.	0.0008 feet North.

From this table it will be seen that the line run down the shaft diverged to the *north* of the true line in every case, the *average* variation from the true line being as great as the *maximum* difference between observations.

On the first day the line of sight which crossed the shaft on its way down passed, near the bottom of the shaft, quite close to a steam pipe. Arrangements were made to have this pipe removed to a greater distance before a second attempt to run the line was made; but when the party arrived on the ground its position had not been changed, though some other changes had been made which improved the conditions a little. On the third date the pipes had been placed in a more favorable position.

Neither of the lines run varied from the true line enough to have caused an error of practical importance at the headings.

With regard to the merits of this method it may be said, that by each set of sights a line above ground, fixed by two points a long distance apart, is transferred in a very direct manner into the tunnel and fixed there by points so far apart that its prolongation will not require more than ordinary care. To accomplish the same result with plumb-bobs several distinct operations would be required.

The working base at the foot of the shaft can be materially increased, when the new method is used, by an enlargement of the shaft near its bottom; while to obtain the same result with plumb-bobs the enlargement would have to extend the whole length.

While considering the causes of error in the new method but two were thought of which might have a tendency to vary from the truth more in one direction than the other. These were:

(*a*) Refraction of the line of sight in the shaft.

(*b*) The bearings of the axis of the telescope not being truly cylindrical.

If there were no hot pipes in a shaft there would probably be no error from refraction; and even if there are such pipes their effect would be neutralized to a large extent by placing them symmetrically on opposite sides of the shaft—a thing which was not done at the Dorchester-Bay Tunnel.

If the bearings of the telescope axis are not cylindrical but somewhat irregular in form, the line of sight will not travel in an exact plane when the telescope is revolved. By repeating the operation with the telescope reversed in the wyes the same deviations from the true plane occur, only they do not happen in the same parts of the plane. It follows, therefore, that on any given line of sight, except a vertical, the average of direct and reversed sights may vary from the truth constantly in one direction if the bearings of the axis are at all irregular in form.

As a precaution against errors of this kind it would be well to avoid the use of a transit with a much worn axis, and to use only an instrument which a good maker would guarantee to have truly cylindrical bearings.

In all other respects, except as above stated, an average of direct and reversed sights will be as liable to vary one way as the other.

Although the term "new" has been applied to the method of tunnel alignment described in this paper the idea of sighting down a shaft is probably by no means new; yet, at the time this method was adopted

and used at this tunnel, the engineers connected with the work knew nothing of its practical application elsewhere. It appears, however, that it was adopted in the Severn Tunnel as early as 1875, five years before it was adopted here.

A description of the alignment of that tunnel is given in *Engineering* of Jan. 20th, 1882, and the method even in details was almost identical with that employed here. At that tunnel the line was run down a shaft 200 feet deep and about 12 feet in diameter. By the method employed a base of 14 feet was obtained at the bottom of the shaft, from which the line was extended two miles. At the headings the lines met almost exactly.

PRODUCING LINES IN THE TUNNEL.

During the earlier stages of the work a transit was used for producing lines, but as the headings advanced the ventilation became worse, so that it was difficult to see even 125 feet on account of smoke and steam, and at times a light distant 75 or 100 feet was invisible. At one time, after wasting two or three days in ineffectual attempts to produce a line fixed by points only 125 feet apart, the use of a string in this tunnel was resorted to for the first time. Although a common twine was used on this occasion the result was so successful that all further use of a transit in the tunnel was abandoned.

In describing the method finally adopted for producing lines with a string it will be premised that the line to be produced is already fixed upon two scales in the roof of the tunnel, about 300 feet apart, and that another scale has been put in the roof 300 feet further into the tunnel.

The first proceeding was to set two posts of 2×3-inch joist vertically in the centre line so far apart as to include the three scales between them. These posts were wedged firmly between the top and bottom of the tunnel. A coarse linen thread or fine netting twine* (a sample accompanies this paper) was stretched between these posts as tightly as its strength would allow, leaving a sag in the middle of about 3 or 4 feet.

The reading on the three scales vertically over the string was next taken, the plumbing being done with a plumb-bob, about an inch long, suspended by a thread from the notch of a vernier sliding on the scale. This apparatus is shown to one-half of the natural scale on the diagram on page 191.

When doing *accurate* work no attempt was made to set the string exactly on the centre line, but rather to put it in a fixed position near the centre. From the scale-readings obtained with the string in this position, the true centre line was found by a very simple calculation.

A check line was run by moving the string a little to one side and taking another set of readings. The production of the line by the two trials seldom varied more than one thousandth of a foot. A very good test of the accuracy of this method was made after the tunnelling was completed. The three shafts of the tunnel are in a straight line

* The ultimate strength of the line was reached when, in a length of 800 feet, the sag was reduced below about 6 feet. It was found to be stronger in proportion to its weight than oiled silk or grass-line; with the further advantage that it cost so little (50 cents for a ball containing about 2,000 feet) that it could be renewed very frequently at a trifling expense. It is quite possible that shoe thread or some other linen line might give even better results.

which was accurately run on top and then transferred to the bottom of each shaft with but little error, giving three points below in the straight line. On one favorable occasion a sight was obtained in the tunnel with a transit from the Middle to the East shaft The accurate centre line thus obtained was run upon the scales in the vicinity of the Middle shaft, and from there it was extended to the West shaft by the string method. Upon reaching the shaft this line varied from that obtained by plumbing from the top only one one-hundredth of a foot.

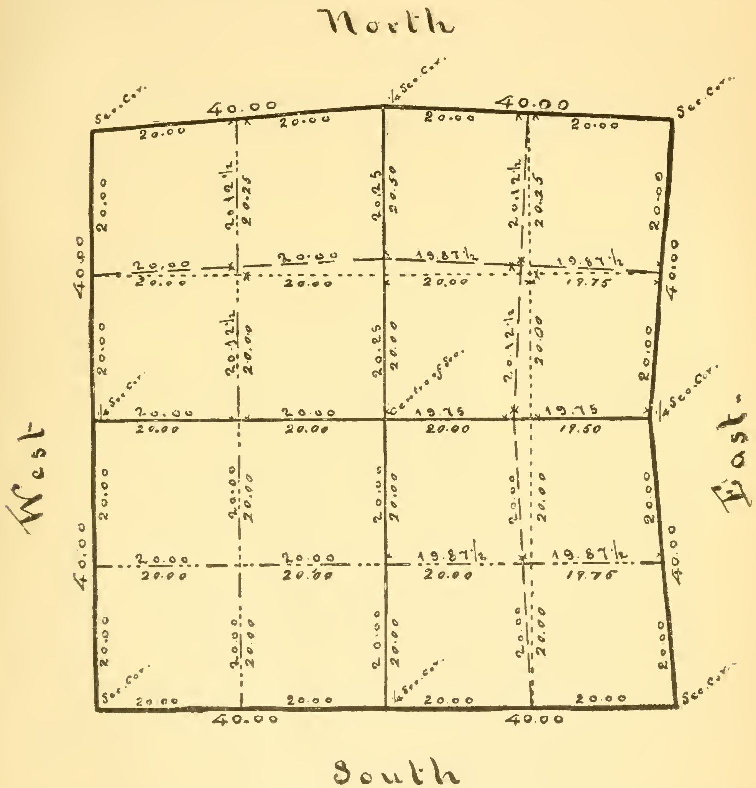
So close an agreement in the result may be in part accidental, yet there was no doubt left in the minds of those connected with the work that much more accurate results could be obtained with a string than with a transit in the smoky atmosphere of a tunnel.

THE PROPER MODE OF SUBDIVIDING A FULL GOVERNMENT QUARTER SECTION.

By Z. A. Enos, Member of the Western Society of Engineers.
[Read May 20, 1884].

I am not aware that the legal mode of subdividing a Government quarter section of land has been determined by the courts, and the opinions of those persons whose official positions, reputations or occupations should give weight to their views, differ widely as to the construction to be given to the laws of Congress on the subject. I find James M. Edmund, Commissioner of the General Land Office, Haw's Manual of U. S. Surveying, and J. Dunn's U. S. Land Laws, holding that a full quarter-section, to be legally divided into half quarter-sections, must have a straight line run through it north and south, connecting the quarter mile or quarter quarter corners on the north and south boundary lines of the section; and then, to properly subdivide it into quarter quarter-sections, another straight line must be run through it east and west, connecting the corresponding opposite quarter quarter-section corners on the east and west boundary lines of the section. The point of intersection of the north and south mile line with the interior or common boundary line of two quarters of the section being the half quarter-section corner, and the point of intersection of the east and west mile line with the other interior or common boundary line of two quarters of the section being the quarter quarter-section corner, and the point of intersection of the two mile lines being the centre of the quarter section. On the other hand the instructions of the Surveyor-General for Illinois and Missouri; Henry A. Wilts, Surveyor-General for Iowa and Wisconsin. and Judge Wm. A. Burt's Key to the Solar Compass, direct that an equal division of each of the four boundary lines of the quarter section shall be made. And a straight line connecting the division points in the north and south boundaries of the quarter section divides it into half quarter-sections; and another straight line connecting the division points in the east and west boundary lines of the quarter section divides the quarter-section into quarter quarter-sections, the centre of the quarter section being the point of intersection of the two straight lines. The accompanying plat of a full Government section and its sub-division into

quarter-sections, half quarter-sections and quarter quarter-sections, will illustrate how the two modes of subdividing a quarter section may produce very different results. If the out boundaries of the section have been accurately surveyed, there will be no difference; but if the survey has been imperfectly made, and the section lines crooked (as represented by the plat—and inaccuracy, in fact, is the rule and not the exception), then a difference in the division will follow. In this instance the full lines show the section and its subdivision into quarter sections, the dotted lines show the first mode of dividing the quarter section, and the dashed



or broken lines the second mode, and the combination of dots and dashes shows the agreement of the two methods.

Neither of the parties above referred to has cited an authority or given a reason for his interpretation of the law, nor against the construction of those holding an opposite view. For the choice I have made between these two conflicting views, I propose now to submit for your consideration some of the reasons that occur to me in favor of the one construction and against the other. By the act of Congress of February 11, 1805, concerning the mode of surveying the public lands of the United States (in order to legally divide a section into quarter sections, establish

their boundaries and the centre of the section or common corner of the four quarter-sections), I believe it is now universally admitted that straight lines must be run through the section east and west and north and south, connecting the opposite corresponding Government quarter section corners. The point of intersection of these straight lines is the centre of the section and common corner of the four quarter-sections: and the halves of these lines (so made by intersection) forming two sides of each of the four quarter-sections, the remaining eight sides having been made by the United States Deputy Surveyor's dividing each of the four sides of the section into equal halves. Thus quarter sections are formed one-half a mile square, with three corners and two half-mile lines, each established by the Government survey, and one corner and two half-mile boundary lines by private survey. Nor would a fourth of a section surveyed in any other manner than the square shape, as above indicated, be sold and patented as a quarter section. For instance, should the four corners of the section be connected by diagonal lines, dividing the section into four equal triangles, these triangles would not be considered quarter sections as contemplated in law. Nor if straight lines were run north and south from points half-way between the quarter corners and section corners, thus dividing the section into four equal parts, each a mile long and a fourth of a mile wide, it would not be a compliance with the act of Congress for establishing quarter sections; and they could not be sold and patented as quarter sections. They would be a violation of the law both in mode of division and in form; and being unauthorized subdivisions and contrary to the manner prescribed by the act of Congress for the division of sections into quarter sections, would therefore be illegal. And any subdivision of such illegal quarter-sections, either into quarter-sections or quarter quarter-sections (whether as east and west halves or north and south halves or quarters) would of course be illegal; the parts must necessarily partake of the character of the whole; for there can be no more self-evident truism than that if the whole is illegal, its several parts or divisions are illegal, and if the parts are legal the whole must be legal. Then upon what principle can it be claimed that by simply changing the name of one of these illegal subdivisions of an illegal quarter section it is thereby legalized. Thus, should we take one of those shoestring fourths of a section, a mile long by one-fourth of a mile wide; for example say the east fourth of the section, and divide it into north and south halves by an east and west line through the quarter corners of the section. Then take one of these illegal halves, say the north half of the east fourth, and call it by the name of the east half of the northeast quarter, and it thereupon immediately becomes a legal subdivision, and that, too, without any regard to whether it corresponds with an actual half of the northeast quarter, either in shape, length of lines or area, ignoring as it appears to me the plain wording and obvious intent of the acts of Congress of 1820 and 1832 in relation to the sale of the public lands, which requires that the corners for half quarter-sections and quarter quarter-sections shall be ascertained in the manner and on the principles directed and prescribed by the 2d Section of the act of Congress of February 11, 1805. Now, in what manner did the Act of 1805 direct that the half

or quarter section corners should be ascertained. Clearly by bisecting the section lines, by running each section line with compass and chain and establishing the half or quarter section corners on true line between, and equal distance from, the corners of the section; or, in the words of the act, "the corners of half and quarter sections shall be placed as nearly as possible equidistant from those two corners which stand on the same line." And then in regard to establishing the centre of the section, the language of the act is, "And the boundary lines which shall not have been actually run and marked as aforesaid, shall be ascertained by running straight lines from the established corners to the opposite corresponding corners," That is, to establish the centre of the section, the common quarter corner for the four quarters of the section, it must be made by the intersection of straight lines from these established corners at the equidistant points, as previously stated, and as by the acts of 1820 and 1832 it is provided that the corners of the half quarter-sections and quarter quarter-sections shall be ascertained in the manner and on the principle by which the half and quarter section corners of the section are ascertained, is it not evident that the lines of the quarter-section will have to be surveyed and quarter quarter-section corners established at equal distances between the corners of the quarter section on each of its four sides, and then straight lines run connecting these opposite quarter quarter corners, thus forming half quarter-sections and quarter quarter-sections. The acts of Congress of 1820 and 1832 did not provide for the sub-division of sections into half sections and quarter sections; they had already been authorized by the Act of 1805 and other acts. Neither did they provide for the dividing the section into eighths or sixteenths of a section, nor for the subdivision of the section in any manner whatever; but what they did provide was that the quarter section, as authorized by the Act of 1805 and other acts, should be divided into halves and quarters, and these subdivisions are by law accordingly so designated as the half of the quarter-section and the quarter of the quarter-section. And a Government quarter section, as we have shown, is a legal subdivision of land having certain fixed or determinable boundaries and corners, that may be easily and accurately ascertained, and the four sides of which are each susceptible of being divided into equal halves, and corners made at the division points, with a centre fixed at the intersection of straight lines connecting their opposite corresponding quarter quarter corners in the same manner and on the principle as directed and prescribed by the Act of 1805 for establishing the quarter-section corners and the centre of the section. And it is not a compliance with the law to divide two of the lines of a quarter section equally and two unequally, or to fix its centre by running straight lines from corners at its equal divisions to corresponding opposite corners in other quarter sections a mile distant. As well might it be claimed that the centre of the section should or could be made by the intersection of straight lines drawn from the quarter corners on the township line to their opposite corresponding quarter corners on the township line. As the law does not provide for the subdivision of a section into eighths or sixteenths, but does provide for the subdivision and sale of the quarter section into half quarter-sections and quarter quarter-sections, and the

entries and patents are so worded, does it not follow that the corners at the equal divisions of the quarter section lines, and the centre at the intersections of straight lines connecting their opposite quarter quarter corners, is the manner directed and prescribed by the acts of 1820 and 1832. You now have the course of reasoning by which I have arrived at my construction of the law. If any one is aware of an adjudicated case in point, or can give other and better reasons for either construction, I should be glad to hear from him ; for light and truth are what I seek, and not controversy.

THE CONSTRUCTION OF FRAME BUILDINGS.

By Clarence O. Arey, Member of the Civil Engineers' Club of Cleveland.

[Read February 26, 1884.]

I had intended when I selected the above title for my paper to take up the different classes of frame buildings, but after starting upon my subject I saw that if I confined myself to the construction of the balloon framed dwelling that I should cover ground enough for one paper. I shall therefore take up the different points in which, according to my ideas, such buildings as constructed in this locality are faulty, and bring forward the qualifications necessary in order to have such a building properly constructed.

The two main requirements to secure this are : First. that there shall be as little settlement in the building as possible, and that whatever settlement there is, shall be the same in amount in all parts of the building ; second, that the frame shall be perfectly stiff against both dead weight and wind pressure.

In starting it must, of course, be taken as one of the conditions that our foundation is solid, that the pieces that carry weight in the cellar bring as much weight upon their footings per square foot as the outside walls have upon their base per square foot.

Also we must consider that the tops of piers carrying the same line of girdles are level, so that they do not require to be completed by putting different thicknesses of plank on them in order to correct their inaccuracies of level.

The old-fashioned braced frame, if properly constructed, fills both the conditions of settlement and stiffness, were it not that there is so much settlement in all parts.

Although the majority of the architects in the East have gone back to the braced frame after a trial of the balloon I do not think that they can accomplish the same results with the degree of economy that the balloon frame gives. The balloon frame is still capable of many improvements, its weakest point being in the ribbon which carries the joists of the upper floors. It has also the disadvantage of having a greater amount of vertical timber than is necessary to carry the weight it receives, in order that the studs may be the proper distance apart for lathing. In order to compensate this, we use studs of a size that hardly gives a wall of sufficient thickness for proper window boxes.

I have been developing a modification of the balloon frame which I

propose to bring into use in my own work, and which, I think, will overcome these difficulties ; but my purpose this evening is to discuss the balloon frame as it is, so that this will not properly form part of my subject.

In discussing the framing the sheathing will be left out of consideration entirely, as being a factor that adds to the strength of the building : for if we depend on the sheathing to carry weight we at once get the question of settlement from the shrinkage of horizontal timber so complicated that it would be impossible to tell the amount of shrinkage timber that we have at any one point of the building, while if the frame is so constructed as to fulfill the condition of settlement the sheathing will then come in place to give the building warmth and general, not entire, stiffness against the wind.

The necessity of equality of settlement is indicated by Fig. 1.

The figure represents a door opening in a cross partition that rests upon joists. If the joists settle more at one end than at the other the floor settles as indicated by the dotted lines, and the door opening loses its rectangular form, while the door, being hung at right angles with the door jamb, will not shut. This point is quite clearly explained in Clark's Building Superintendence.

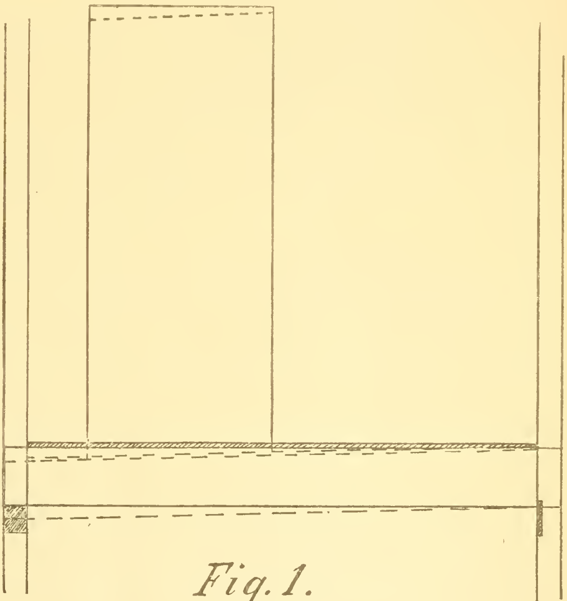


Fig. 1.

To properly discuss the conditions of stiffness and equality of settlement it will be better to take the building in its different parts and consider what is necessary in order that each part may fill the requirements.

Sills, Girders, and Plates.—I consider the sill built of plates, and so common in this locality, to be thoroughly bad. In the first place in a sill or beam built of more than one horizontal thickness, there is a loss of strength in exact proportion to the number of thicknesses employed. That is if a beam of two horizontal thicknesses you have exactly one-half the strength of the same amount of timber in one thickness. In a sill of three thicknesses you have only one-third the strength of a timber of the same dimensions in one thickness. To prove this we have simply to fill Rankin's formula for beams.

$B. M. = n f b h^2$.

$B. M.$ is an abbreviation for bending moment.

n being a constant depending on the section of the beam.

f being a constant depending on the material used.

b and h being the breadth and height.

A beam of any number of horizontal thicknesses unless properly keyed and bolted together must be considered as so many separate beams of the thickness of each, so that in getting the comparative strength of a beam of one thickness, and a beam of several thicknesses with the same total dimensions, we must fill the formula for the first case with h representing the total depth of the beam, and for the other with h representing one thickness of the beam, and multiply the result by the number of thicknesses.

All the factors excepting h remain constant.

For a beam of two thicknesses h being the depth of the beam of one thickness, h would become $\frac{1}{2} h$ and squared $\frac{1}{4} h^2$ doubling for each part of the beam it becomes $\frac{1}{2} h^2$. In the same manner for three thicknesses the h^2 for one thickness becomes $\frac{1}{3} h^2$. Substituting n for the number of divisions we obtain for n thicknesses $\frac{}{n}$th of the strength for one thickness.

I have perhaps been unnecessarily explicit on this point, but my excuse is that it is a fact so commonly misunderstood outside of the engineering profession.

During the summer of '81 I noticed in a large dwelling going up on the Chamberlin Allotment, in this city, that the sills were made of two pieces of 2 inches × 6 inches, spiked together.

Examining them over one of the cellar window openings I found a deflection of fully a ¼ inch in a span of about 3 feet 0 inches. By this we see how such a sill will settle over an opening; and also if the foundation settles for a short distance in any part of the building how this class of sill will settle with it.

For different reasons from the ones I have against built sills I object to girders built out of joists on edge and spiked together.

First, you cannot make a good splice and have it entirely upon a bearing. Bolsters are not allowable in this class of building, on account of bringing in too much shrinkage timber.

In this connection I will mention a case where I made some alterations in an almost new dwelling on Willson avenue. I found that the girders in the cellar were made of three pieces of 2 inches × 10 inches on edge. In a span of some 8 or 9 feet the middle joist was spliced about 3 feet from one of the piers. The splice being simply one joist ending and another commencing, leaving really only a double joist to form the girder.

Second, as we cannot get absolutely dry timber in the market several thicknesses of timber nailed together without any air spaces between them have a decided tendency to dry rot. If these girders were keyed apart, leaving an air space between each division, after the manner of the chords of a Howe truss, they would be in all respects equal, if not superior, to a solid timber.

Having considered sills and girders with regard to strength, there still remains the consideration of equal shrinkage throughout the building. It will be assumed that all of the timber is of sufficient strength to avoid

appreciable deflection. I suppose that it is understood that timber shrinks across its grain, but not lengthwise of its grain to any appreciable extent. By the term shrinkage timber, which I shall frequently use, I mean the timber which lies horizontally in a building, and which carries joists, floors or partitions upon it. Let us take a building in which the inside partitions, which carry joists, are carried by girders upon piers, and all studs that carry joists go through between the joists at their foot and rest upon the sill, girder or plate below.

If the sills and girders are of unequal depth the first floor may be made to have equal settlement by sizing the joists of this floor unequal amounts at the two ends—that is, if we have a 6 × 6 inch sill and 8 × 10 inch girder on edge, on account of having 4 inches more timber vertically, we require, in order that the floor may settle equally, 4 inches less of the joists resting on the girder than on the sill, as in Fig. 2 ; thus giving us 14 inches of shrinkage timber at each end.

But with this arrangement the trouble comes in a balloon frame when we reach the third or attic floor. For the second floor we need at least a 4-inch plate on the top of the first floor studs that rest upon the girder; this, with the case already taken, will give us 14 inches of shrinkage timber without the second floor joist timber. If we set this plate into the joists 4 inches, the joists being 2 × 10 inches, we shall have 20 inches of shrinkage timber at this inner end of the joists. At the outer end we have 6 inches from the sill ; the ribbon will probably set into the joists so as to leave 9 inches shrinkage timber in them. This makes 15 inches. To make up the 20 inches we need a 5-inch ribbon. The shrinkage of the ribbon not being exactly certain on account of its nailing, it would be better to use a 6-inch one.

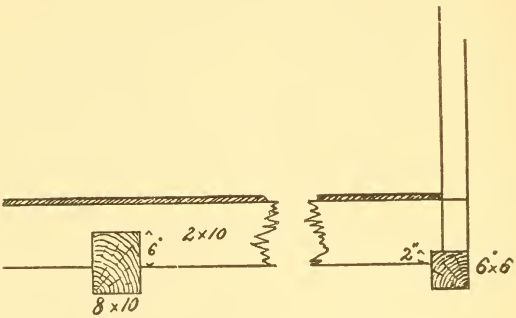


Fig. 2.

Under the inside ends of the third floor or attic joists, if there are 4 inch plates at the top of the second floor studding, we have, adding this to the 14 inches below, 18 inches of shrinkage timber.

Under the outside ends we have, adding the 4 inches of the plate to the 6 inches of sill, 10 inches of shrinkage timber.

This would require us to cut 8 inches further into the inner ends of the attic joists than the outer, which is impracticable. Now let us start with the sills and girders of the same depth and see how it simplifies the matter. (This case illustrated by Fig. 3.) I do this in practice by using 6 × 6 inch sill and a 6 × 10 inch or a 6 × 12 inch girder laid flat; the distance between the piers being proportioned to the weight.

If the first-floor joists are sized out so as to leave the same amount at each end they will settle evenly as the timber dries. If a 4-inch plate is used on the top of the interior carrying partitions under the second floor, and a 6-inch ribbon (considered as equivalent to 5 inch) is used in the outside studding under the same floor, and is set into the joists 1 inch, we have 20 inches of shrinkage timber at each end of the joists for the sizes given in Fig. 3. I object to a 2-inch plate on the top of the studding that carries the second floor joists as being too light for a span of 16 inches to carry both the second-floor joists and the second-floor studding resting directly upon it. If this plate only carried one set of joists and not the partition above it, it would be sufficient. If under the

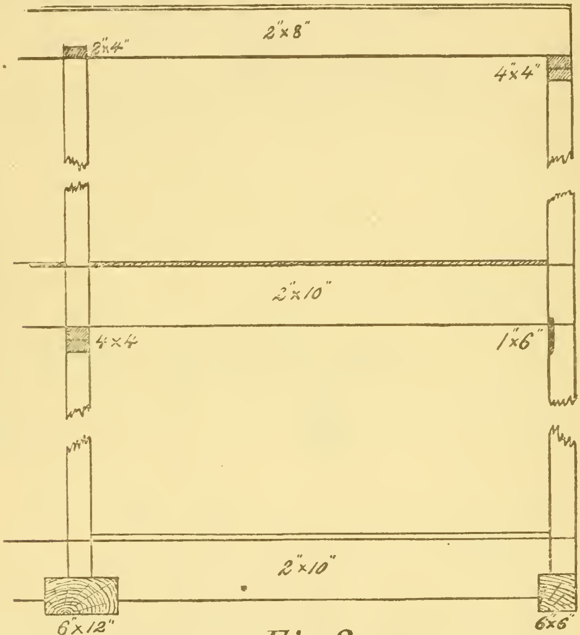


Fig. 3.

attic joists a 4-inch plate is used on the outside wall and a 2-inch plate at the top of the inside partition, and this latter is set into the joists above it 2 inches, we have 18 inches of shrinkage timber from the foundation to the top of the attic-joists at each end of them. In practice if the attic have no finish whatever I generally use a 4-inch plate on the top of the interior bearing partitions, just under the attic joists. If it is desirable to raise the roof so as to have some height in the attic at the eaves, by setting a 6-inch ribbon into the studding and letting it into the attic joists 1 inch, the same as is done under the second floor, we still keep both ends of our joists resting on an equivalent amount of shrinkage timber.

There came under my attention during the past summer a frame

dwelling in which there were 6 inches more horizontal timber at the inner ends of the first-floor joists than at the outer ends, 10 inches more in the second-floor, and 26 inches more in the attic floor. I have heard the owner since complain that the plaster cracked in all the angles, of course, as by settlement the shape of the cross walls change from rectangles to acute and obtuse angled parallelograms, the junction between these cross walls and the supporting walls must be severed, as plaster has no element of elasticity.

In this connection it may be well to mention that cracking of plastering is more generally the fault of the carpenter than the plasterer. Splintering, which is hardly the correct name for it, is generally caused by unslacked lime, or by work done in winter under artificial heat, under which conditions good work can never be obtained.

Framing Over Openings.—For openings not over 3 feet 0 inches in width I find that doubled 2-inch plates set into the studding on each side of the opening have sufficient strength. This setting in, although neglected by

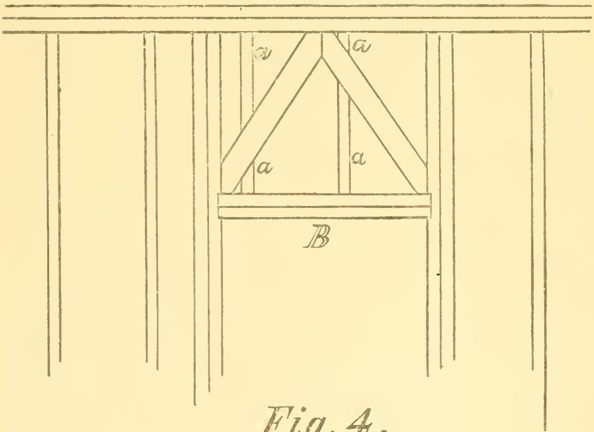


Fig. 4.

the carpenters unless carefully watched, is absolutely essential; otherwise we put in a timber amply strong, and hold this timber by a few nails which have nothing like the necessary strength.

Over openings wider than this I think it is best to truss. Although a joist set into the studding on edge is strong enough, unless it is absolutely dry it complicates our problem of skrinkage. In trussing it is necessary to see that the truss is a truss, and not a semblance of one held in place by a few nails.

It is wonderful what an amount of ignorance is displayed in the construction of simple trusses. Heavy timber is put in with no duty to perform whatever. Struts are used where there should be ties. Timbers of a size only sufficient to withstand a direct thrust or pull are put under heavy bending moment. We hardly see all of these conditions in the little trusses of which I am speaking, but there are plenty of them built that might as well be left out as far as any purpose being accomplished by them is concerned. Perhaps the simplest form of a good truss for such

places is that shown in Fig. 4. The pieces *a a a a* are set in after the truss is built for the purpose of lathing.

If the truss is very flat in proportion to its height, the doubled studding on each side of the opening will not be sufficient to withstand the horizontal thrust, and the struts will either need to be set into the tie *B*, or the two or three studs on each side of those forming the opening will want to be blocked together at the level of the tie *B*.

Stiffening the Walls of the Building against Wind Pressure.—This is a precaution to which generally very little attention is paid in balloon frames. This end may be accomplished in several ways, as follows: By setting into the studding diagonal 1-inch dressed boards at the angles of the building, and nailing to every stud which the diagonal crosses; by running a row of zigzag bridging all around the building between the studding; by bricking up a short distance between the studding. This fixes the lower ends of the studs solid and makes them all act as beams fixed at one end. By covering the walls with narrow matched sheathing. Covering the wall with common sheathing is not an entire precaution against displacement by wind pressure, because by a very slight giving way of the wood against the side of the nails each board may have a parallel motion in the same manner that a parallel ruler acts. The matched sheathing, to be efficient, must be nailed on both edges, and not simply blind-nailed like flooring. In this case the matching and the fact that the narrowness of the boards makes less leverage between each pair of nails produce the superiority for this purpose over common sheathing. I do not consider that even the matched sheathing is as good a means of resisting wind pressure as the first few mentioned.

The Order of Progress.—It is customary with some contractors to space the studding equally distant all around the building, then to sheathe, and after this to cut out the openings wherever they may come. I have never seen a case of this in which the framing around openings was not a mere pretence, the framing studding being merely tacked into place against the sheathing, the studding that was originally set up carrying the weight across all openings to the studding. Sometimes the openings are not even framed till the roof is raised, then if the opening is wide and the roof is heavy, the wall-plate, being unsupported during the cutting out, settles out of level, where it permanently remains. It is my custom now to specify that the building shall not be sheathed till all openings have been framed, and that the roof shall not be raised till the building has been sheathed.

Before any lathing is commenced it is necessary to see that all angles have been made solid, and in making an angle solid it is necessary that the end studs of the partitions that form the angle shall be against each other. This is so that each room may be lathed by itself and have no lath running through from one room to another. When the laths run through in this manner the two angle partitions have no connection with each other, and any jar in one of them will not affect the other, so they spring apart and crack the plastering down the angle. Where a frame partition joins a chimney there is only one way of preventing a crack, and that is by furring all around the chimney with wood, and this I should not recommend unless the chimneys have 8 inch outside walls.

Sheathing and Siding.—Sheathing a building on the outside is altogether preferable to sheathing it on the inside. When a building is sheathed on the inside the spaces between the floor joists are generally left open, letting the cold air pass in, and making cold floors ; also the clapboards on the outside, being only ½ inch thick in their thickest place, have a tendency to spring in different curves between the studding, thus opening a space for the inlet of cold air. Sheathing on the inside has the disadvantage of having no grip on the angles of the building ; and any building paper used in this case loses half of its efficiency by having nothing to hold it flat in place and keep its lapped joints tight together. On the other hand, if the building is sheathed on the outside the sheathing runs up continuously, gripping the angles and covering the ends of all joists. It keeps the clapboards close against each other and packs the building paper tight between the clapboards and sheathing. In comparing these two methods of work I have spoken of the building as if clapboards were the only covering. I consider it the only good covering to the outside of a frame building excepting shingles. Drop-siding either leaves large spaces to hold water, if the casings are laid on top of it or it splinters on the end from the lack of an air space behind it if it is butted against the casing. Clapboards from being thinner at one end than at another, and from their lapping each other, leave a triangular air space between every two consecutive ones and the sheathing, which greatly enhances their durability.

In general air spaces between consecutive pieces of timber in a frame building are essential to its durability.

Roofs.—These have both dead weight and wind pressure to resist. I shall leave out of consideration roofs covering large spans, requiring framed trusses, and take up only the ordinary roof and such trussing as may be put together with spikes acting as rivets or pins. My idea of the ordinary roof is that the hips, valleys, ridges and wall rafters should form a frame, not necessarily strong enough to carry the whole roof, but strong enough to act as a decided stiffener to the whole. The common rafters in this case act almost entirely as filling. The valley rafters are almost always made too light, the fact not being taken into consideration that they have to carry the weight that is on all the rafters that butt against them.

Where the rafters are 2×6 inches, a doubled 2×8 inches is necessary for the valley rafters. Hips and ridges should never be less than 2 inches thick, and deep enough to receive the diagonal dimensions of the rafters. If these are less than 2 inches thick we do not have straight but wavy ridge and hip lines. In one of the first buildings that I erected in this city, which was built by the day, I had specified the ridges 2 inches thick. As the building went on the owner wished to economize as much as possible, and a 1-inch ridge was put in. This building happened to have an exceptionally long ridge and a good place to illustrate the weak point of a 1-inch ridge-pole. When the attic floor was laid I took the owner into the attic at one end of the ridge and had him sight along it. The straightness of the ridge averaged all right. It was as much out on one side as it was on the other ; it was like Mark Twain's watch, which was all right at 12 o'clock at noon every day, but the rest of the time he could

not tell whether it was slow or fast. The workmen employed on this building were experienced and careful men.

The attic of a dwelling may just as well and cheaply be made clear and unobstructed between its outside walls as to be all cluttered up with posts supporting angles of the roof. If the roof is properly framed it does not need this, even if it has a deck. If in each case where two valley rafters come together one of them is run through to the ridge or deck plate, if no spliced timber is used and if the roof is properly braced against the wind, the most complicated roof can be made to stand without intermediate supports. Of course each case will want special study. When supports are put in the roof is framed to rest on them, so that they cannot be removed, and if ever it becomes desirable to divide the attic into rooms they are always just in the wrong place. If the attic is ever furnished off as a dancing hall the posts are terribly in the way. It is much easier to dodge two couples than it is to dodge two couples and a post at the same time. In the more complicated roofs without decks, the timbers run from so many different directions that they brace themselves against the wind. Take, however, a long narrow building, or a building with a deck, and they need bracing against wind pressure.

In the case of a long building with the gables at the end and where the roof starts above any floor, there is nothing to prevent the rafters moving transversely to the building and parallel to each other when the rafters are only tied by collar beams. Such a roof very much resembles the ordinary railroad bridge trusses in principle of lateral pressure. An equivalent to the diagonal bracing of the horizontal panels in these bridges is all that is needed here. This may be accomplished by dividing the building lengthwise into approximately square panels, then laying joists flat on the top of the collar beams, so as to form diagonals to these panels, and then spiking them to every collar beam. This construction may of course be varied for special cases. In deck roofs our problem is very much that of the ordinary trapezoidal truss, which is perfecly stiff under dead weight but liable to give under wind pressure. If we tie the angles of the trapezoid there is no chance for it to change its form, provided of course that our timbers are heavy enough not to be affected by what little bending moment is brought upon them by this operation. I have put up quite a number of roofs leaving a clear attic or barn loft, and by using the precautions mentioned, varied to suit each case, have found them perfectly stiff, making the building more convenient and appearing much better inside. Now that we are on the roof I think it is as good a place to stop as any, leaving you to get down as best you may.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 16, 1884:—A regular meeting of the Boston Society of Civil Engineers was held this evening at 7:45 o'clock, President Vose in the chair; twenty-one members present.

The record of the last meeting was read and approved.

The following, prepared by Eliot C. Clarke, on the death of Frank A. May, a member of this Society, was read by the Secretary.

FRANK A. MAY.

By the wreck of the ill-fated "City of Columbus" the Boston Society of Civil Engineers lost one of its most promising and congenial members. Mr. May was born in Boston, May 1, 1854. He was educated at the Roxbury High School and the Institute of Technology. His first professional work was upon the Hoosac Tunnel, where he was employed for seven months. For three years thereafter he was employed upon the Main Drainage Works of Boston, after which he had charge of a party on the Northern Pacific R. R. Being recalled as a witness in a suit, he was offered a position on the New York & Boston Inland R. R., and during 1881–2 made surveys for that road, the latter year being the principal engineer in the active employ of the company.

Mr. May also made a survey of the ponds and mill privileges on Rumford River, in the town of Mansfield, Mass., for the B. & P. R. R., and in 1883 had charge of a survey to determine the boundary line between the States of Massachusetts and Rhode Island. On the night of the wreck he sat late in his stateroom making calculations of latitude and longitude in connection with this survey. At the time he was on his way to accept a position in the South.

In his work Mr. May was conscientious and painstaking. He was by nature modest and retiring, so that while all found in him an agreeable companion, comparatively few appreciated his worth. It may be said of him few had so high an ideal or so nearly attained to it.

On motion it was voted that a copy of this memorial be placed upon the records of the Society.

On motion of Mr. Fred. Brooks, it was voted that the thanks of the Boston Society of Civil Engineers be extended to Mr. J. R. Robinson for his interesting paper on the "Safety-Seam Steam Boiler."

Mr. Charles Walker Raymond was proposed for membership, recommended by Messrs. George L. Vose and H. A. Carson.

Mr. Henry F. Walling was proposed for membership, recommended by Messrs. George L. Vose and A. E. Burton.

Mr. James W. Johnson was proposed for membership, recommended by Messrs. George L. Vose and A. E. Burton.

Messrs. Seth Perkins and Henry H. Carter were elected members of the Society.

Prof. William Ripley Nichols read a paper on "The Filtration of Certain Saline Solutions Through Sand."

Mr. E. W. Bowditch read a paper on "Sanitary Matters in Connection with Isolated Country Houses."

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEER'S CLUB OF ST. LOUIS.

MAY 21, 1884 :—231st Meeting.—The St. Louis Engineers' Club met at the Mercantile Club at 8 o'clock. The minutes of the previous meeting were read and approved. The following gentlemen were elected members: Prof. F. E. Nipher, Willard Beahan, C. E. Jones and H. W. Baker. Mr. Emil C. Goldstein was proposed for membership by A. H. Blaisdell and E. D. Meier. The committee on excursions reported that the United States steamer Gilmore would be put at the disposal of the club by Major O. H. Ernst for a trip to Crystal City and return, on Saturday, May 31. The proposition was accepted, and a vote of thanks tendered Major Ernst for his kind offer.

A telegram was read from Col. C. Shaler Smith from Augusta, Ga., stating he could not be at the meeting to fulfill his engagement to read a paper. A similar communication was read from Prof. Nipher.

Mr. Howard Constable read a paper on "The Interior Rusting of Wrought Iron Columns," accompanying his remarks with specimens taken from various existing structures. These structures, ninety-five in number, were scattered through eight States.

This paper was very generally discussed.

Prof. Potter offered some remarks on a case of corrosion in iron flues at Iron Mountain, caused by water condensation in the stack.

Mr. Constable exhibited maps showing the plans and profiles of the oil pipe lines from Western Pennsylvania to the seaboard and to Lake Erie, with remarks as to the pumping stations, etc.

Mr. Alderdice offered some figures to prove that a boat with a wind motor may be made to move into the eye of the wind.

[*Adjourned.*] J. B. JOHNSON, Secretary.

JUNE 4, 1884 :—232d Meeting—The St. Louis Engineers' Club met at the Mercantile Club at 8 P. M., 25 members being present.

The following gentlemen were proposed for membership: A. L. Sieghortner, by Frank H. Pond and Wm. H. Bryan; Eliot C. Jewett, by Wm. B. Potter and H. A. Wheeler; and A. N. Smith, by Hubert Taussig and M. L. Holman.

The committee on excursion reported as follows:

To the Engineers' Club of St. Louis:

GENTLEMEN: The committee on excursion beg leave to report that on Saturday, May 31, in accordance with the resolution adopted by the club at its last meeting, 38 members of the club and 12 guests joined in an excursion on the United States engineer steamer Gilmore down the river as far as Crystal City and back again. The party wa accompanied by Lieut. F. V. Abbot, Corps of Engineers, and Mr. D. M. Currie, assistant United States Engineer in charge of the Mississippi River works near St. Louis, who explained to the Club the plans and methods of the works for the improvement and regulation of the river between St. Louis and Kimmswick.

On reaching Crystal City (at 11:30 A. M.), Mr. Hitchcock, president, and Mr. Neale superintendent, of the plate-glass works, met the party and conducted them through the works, showing them the glass in every stage of manufacture, from the digging of the sand to the finished product in the shipping-room. To make the exhibit more com

plete, the cast of one of the furnaces was delayed several hours, so that it might be witnessed by the Club.

On re-embarking (about 1:20 P. M.) a lunch was served and met with unanimous approval. Two landings were made on the way back, one at Bushberg to inspect the U. S. snag-boats, and other boats for river improvement now lying there, and another at Twin Hollows to examine the methods of hurdle construction. The city was reached at 7 P. M.

The weather during the day was all that could be desired, and the whole excursion a complete success.

The thanks for the day's pleasure are due to Maj. O. H. Ernst, U. S. Engineer Corps, who kindly placed the boat at our disposal, and to the officers of the Crystal Plate-Glass Company for their great courtesy in conducting us in person through their mammoth and extremely interesting works.

ROBT. MOORE,
D. C. HUMPHREYS,
J. B. JOHNSON,
Committee.

It was unanimously voted that the President extend the thanks of the Club to Maj. O. H. Ernst for the use of the steamer placed at their disposal, and to the officers of the plate-glass works at Crystal City for the courtesy extended to the members of the Club while visiting their works.

Prof. F. E. Nipher then proceeded to discuss a method of determining the mechanical efficiency of an electric generator and motor. He illustrated by drawings the mechanical devices used by him in some recent experiments to determine the ratio of the amount of work done by an electric motor to the work done on the electric generator by a steam-engine. He also exhibited diagrams, constructed from experimental data, showing the method of determining the conditions for any efficiency at minimum speeds of generator and motor.

Dr. Adams explained why he did not get a higher efficiency at Washington University in his combination of generator, motor and engine. They were very poorly suited to each other, and so only obtained from the motor some 35 per cent. of the work done on the generator by the engine. With the best combination of these three instruments, an efficiency of 70 per cent. could be obtained.

The subject was generally discussed by Messrs. Sedden, Holman, Taussig and others.

The subject of the use of compressed air by the Bridge Company in working their switch and signal system in East St. Louis, Main street and Poplar street, was to be discussed by Col. C. Shaler Smith. In his absence the subject was informally discussed by the members of the Club.

Dr. Adams explained that every electric couple consisted of a generator, a circuit and a motor. Generators have been made, notably Hopkins' improvement on Edison's machine, which returned 94 per cent. of infused energy. Motors can be constructed to give 85 per cent. The loss in transmission between the two has been reduced to two per cent., as in the case of Dr. Siemens' electric railway in Berlin. Consequently a fair estimate of the amount of work that could be realized out of a properly constructed couple would be represented by $90 \times 90 \times 85$, or 68.8 per cent.

Prof. Nipher thought that the Club ought not to discuss a transcontinental electric railway—that is a problem for the future. If George Stephenson had started out to build the Missouri Pacific he would have failed.

Prof. Woodward invited the members of the Club to attend the graduating exhibitions of the dynamic, civil and mining engineering classes of the Polytechnic School of Washington University, and the meeting adjourned.

J. B. JOHNSON, Secretary.

WESTERN SOCIETY OF ENGINEERS.

MAY 20, 1884:—The 186th meeting was held at 4 P. M., Vice-President Randolph in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Artingstall, for the Committee on Order of Proceedings, reported that this Committee recommended that the order of proceedings be amended so that Nos. 3 to 7 inclusive be omitted at the first meeting in each month.

Action on the report was deferred till the next meeting.

The Secretary reported having received photographs of the following members: J. M. Healy, C. H. Hudson, Walter Katté, G. A. M. Liljencrantz and H. C. Nutt.

The Secretary announced the death of Mr. George Burt Lake, a Member of the Society, and read a short Memorial paper, which was ordered printed, and the Secretary requested to send a copy to the mother and to the widow of the deceased.

The Committee on Surveys and Topography presented a paper from Mr. Z. A. Enos, "The Proper Mode of Sub-dividing a full Government Quarter Section," which was read and ordered printed.

The Committee on Order of Proceedings reported that in pursuance of an understanding with several members, they had provided a lunch as an experiment. It was voted that the report of the Committee be accepted with thanks.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

MEMORIAL—GEORGE BURT LAKE.

It is my sad duty to announce the death of George Burt Lake, a valued member of this Society, at his residence in Topeka, Kansas, of pneumonia, after an illness of a few days, on the 27th of April last.

Mr. Lake was born December 9, 1844, in Howell, Michigan, completed his education at Ann Arbor, and graduated there with the degree of Civil Engineer in the class of 1869. From that time he was continually in the practice of duties pertaining to his profession until his death.

In 1871 he entered the service of the Atchison, Topeka & Santa Fe Railroad Company, as Assistant Engineer; in 1876 he was appointed Division Superintendent; in 1878 he was made Superintendent of Track and Bridges; in 1881, Principal Assistant Engineer; and in March 5, 1884, was appointed Chief Engineer.

He became a member or this Society May 6, 1879, and, while prevented by residence at a distance from taking an active personal part in the Society's affairs, has from time to time manifested his interest in its welfare.

Mr. Lake was married in 1878, on Christmas day, and leaves a widow and two children to mourn his loss. His mother also survives him.

Personally, Mr. Lake was an example of the highest type of manhood, a Christian man and a Christian gentleman. His success in life was due to his own exertions and his own sterling qualities and virtues. His associates, the general officers of the corporation he served so long and faithfully, in expressing their grief at his death, speak of "his stainless character in all the relations of life as known by every one with whom he was associated or with whom he was brought in contact," and we, the members of this Society, in echoing this faint meed of praise, desire to record our gratification that our Society can claim a reflected honor from the worthy life of our departed friend.

In the life of Mr. Lake we read a lesson which may be well studied by every member of the profession, stimulating the young to honorable exertion and the development of the higher attributes of manhood, and bringing to the mind of the older engineer the thought that the structure which is to stand as the most enduring of all his works, and therefore the one which should be the best studied for its harmony of proportion and adaptation for the limitless possibi ities of the future, is his own personal character.

To his mother, his widow and his children, we tender our deepest sympathy in their great affliction, and assure them that we shall cherish with them the remembrance of the virtues of one who was honored and esteemed as a son, a husband, a father and a friend.

June 3, 1884:—The 187th meeting was held at the Society rooms at 4 P. M., President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

The report of Committee on Order of Proceedings was taken up for discussion, and it was voted that the report be recommitted to the Committee.

Mr. Jones, for Committee on Courtesies to the American Society of Mining Engineers, reported the action of the Committee, and presented a bill for expenses incurred.

The report was accepted and the bill ordered paid.

The Committee on Order of Proceedings presented a bill for the lunch provided at the last meeting, which was ordered paid.

The Secretary presented a bill from the Association of Engineering Societies, dated May 21, 1884, on account, for $204, and this amount was ordered paid.

Announcement was also made of the receipt of photograph portraits of Messrs. T. J. Nicholl and G. R. Bramhall.

Mr. Randolph, who was to exhibit plans, etc., of Western Indiana Railroad Passenger House, being called away by business, the exhibition of these drawings was postponed.

[*Adjourned.*] L. P. Morehouse, *Secretary.*

June 17, 1884:—The 188th meeting was held at the Society rooms at 4 P. M., Vice-President Randolph in the chair.

The minutes of the preceding meeting were read and approved.

The Secretary read a letter from the American Institute of Mining Engineers, expressing the thanks of that Society for courtesies received during its recent meeting in Chicago.

The Secretary also announced the receipt of a photograph likeness from Mr. Lyman Bridges.

It was voted that at the next meeting the Committee on Order of Proceedings provide a lunch for that occasion.

Mr. Bates read a paper on "The Duty Test of a Cast-Iron Boiler." It was voted that this paper should be printed.

Mr. Randolph exhibited the plans and drawings for the new Union Passenger House of the Western Indiana Railroad Company, on Polk street, in Chicago.

[*Adjourned.*] L. P. Morehouse, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

APRIL 22, 1884:—Adjourned meeting held. President Holloway in the chair. Minutes of last meeting read and approved.

The Committee on Programme, consisting of one member selected from each of the five sections or committees representing the various professions, reported that the committee consisted of the following persons:

On Railroad Engineering, H. C. Thompson.

On Mechanical Engineering, E. H. Jones.

On Civil Engineering and Surveying, Hosea Paul.

On Architecture, John Eisenmann.

On Scientific Pursuits. N. B. Wood.

With Prof. John Eisenmann as Chairman and Hosea Paul as Secretary.

Each committee was requested to meet at as early a day as practicable, and decide upon a list of papers to be submitted to the Committee on Programme.

The assignment of papers for the year was set as follows:

Papers on Civil Engineering and Surveying, in May, October and April.

Papers on Railroad Engineering, in June and November.

Papers on Mechanical Engineering, in July and December.

Papers on Architecture, in August and January.

Papers on subjects pertaining to scientific pursuits, in September and February.

The Committee favors the holding of adjourned meetings for the discussion of special papers rather than the taking up of the time of regular meetings.

S. J. Baker read a paper entitled "The Original Surveys of Cleveland," for which he received a hearty vote of thanks.

The Secretary was instructed to have 300 copies of the list of officers and members, committees, etc., printed.

B. F. Morse read extracts from reports upon engineering structures, showing that piles were frequently loaded with sixty to seventy tons to the pile, as against a twenty-ton load as used in the construction of the Cleveland Viaduct.

Mr. Charles Latimer re-read a poem entitled "The Three Seventies," written by our venerable fellow-member, John H. Sargent, for a family gathering upon the occasion of his seventieth birthday. It was ordered published with the other Club matter.

The member of the Board of Managers on Joint Publication was requested to confer with the other societies upon matters pertaining to such publication.

Adjourned.] M. W. KINGSLEY, Rec. Sec'y.

MAY 13, 1884:—Regular meeting held, President Holloway in the chair.

Minutes of last meeting read and approved.

Mr. J. J. Laman presented the Club with a bound volume of Physics and Hydraulics of the Mississippi River.

Mr. Claflin reported that satisfactory arrangements could be made with the Connotton Valley Railroad for the proposed excursion to the Bessemer Steel Works, at Newburgh.

The following persons were, upon the recommendation of the Committee on Membership, elected active members of the Club: Wm. M. Wood, N. S. Possons and V. E. Gregg.

The President stated that the Institute of Mining Engineers of Ohio were to hold a meeting in Cleveland on June 25, and hoped that the members of this Society would endeavor to meet them, and appointed the following committee in reference to the same: Chas. Latimer, M. L. Deering, E. H. Jones, Alex. E. Brown and B. F. Morse.

Prof. Eisenmann read a paper upon the "Eccentricities of the Transit, with

reference to horizontal angles." In view of the proposed visit of the Club to the Bessemer Steel Works, President Holloway, by request, read a paper entitled, "Henry Bessemer and his Inventions."

On motion of Mr. Rawson, the following resolution was adopted :

Resolved, That the Treasurer be and is hereby authorized to pay to the Association of Engineering Societies for publishing the Journal an amount not to exceed $1.50 per member based upon the present mailing list, such amount to be paid upon receipt of bills duly certified.

Upon motion, amendments to the constitution were made the first order of business for the June meeting.

[*Adjourned.*] M. W. KINGSLEY, Rec. Sec.

JUNE 10, 1884 :—Regular meeting held. President Holloway in the chair. Minutes of last meeting read and approved.

On motion, the Committee appointed at the last meeting, in reference to the proposed meeting of the Ohio Institute of Mining Engineers, in this city, on the 25th inst., was continued, and, with the President added, was empowered to take such action upon the part of the Club as seemed best, with reference to the visiting members.

The President announced that the discussion of the proposed amendments to the constitution was now in order.

Mr. Cully moved that the amendments proposed by Messrs. Rice and others at the meeting of February 12, 1884, be now adopted, which amendment was to take the place of Sec. 1 of the constitution, and applies to all future application for membership, in which only such persons shall be eligible to membership as have pursued one of the following professions for a livelihood for the space of five years (2 years' allowance being made in favor of graduates from scientific schools), to wit : civil, mechanical, and mining engineering; architecture, astronomy, geology, and analytical chemistry. Amendment lost.

Mr. Rawson suggested as a substitute for the above that the proposition introduced at the meeting of Nov. 13, 1883, to create a new class of membership entitled Associate Members be adopted, and that hereafter any person who is now or has been engaged in any one of the professions named in the preceding amendment, proposed by Messrs. Rice and others, shall be eligible as *active* members of the Club, and that all other persons engaged in scientific or other pursuits relating to some one of the professions therein named, whom the Club may desire to elect, shall be eligible to *associate* membership in the Club, and that, as already provided for the three classes of membership now existing—active, corresponding and honorary—only active members shall have the right to vote and hold office.

The above suggestion having been received favorably, a committee of three, consisting of Messrs. Rawson, Hyde and Culley, was appointed to present the same in proper form, with other amendments, made necessary thereby, at the next meeting of the club.

On motion, the Treasurer was authorized to pay the bill of Vincent Borstow & Co. for reseating and repairing chairs.

[*Adjourned.*] M. W. KINGSLEY, Recording Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

THE ORIGINAL SURVEYS OF CLEVELAND.

By Samuel J. Baker, Member of the Civil Engineers' Club of Cleveland.

[Read April 22, 1884.]

In presenting this paper to the Club, it may be well to state that as it is addressed to our members generally, and not to our surveyors alone, I have made it somewhat more explanatory than I should have done were the latter the case. Accordingly, I shall preface what may be said of the surveys of our city, with some historical statements showing how the surveys came to be made, which I have condensed from the writings of our honored fellow-member, Col. Charles Whittlesey, who has, especially in his "Early History of Cleveland," stored up for us such a great stock of valuable information on this and all kindred topics of our pioneer history, and to whom I here make all due acknowledgments. Doubtless none of our members are unaware that our city forms part of the "Western Reserve," but all may not know what is meant by this title, and as the first surveys of our city were made in connection with those of the tract so called, it will be necessary to go back a long time in history in order to show both the origin of the title and of the surveys. Mr. Hosea Paul has, in his valuable paper to the Club on "The Systematic Division of Land," briefly outlined some of this history, which I shall give more in detail.

The Colony of Virginia as originally granted embraced all of North America between the 34th and 48th parallels of north latitude. James I. of England divided Virginia into a north and a south part and granted the same to two companies called respectively the "London" and the "Plymouth" company. To the latter company was granted, by a Charter dated November 3, 1630, the north part, being all the land between the 40th and 48th parallels, from the Atlantic to the mythical "Great South Sea," to be forever called "New England." This grant "covered New York, Canada and most of Pennsylvania and Ohio and the Northwest." In the same year, the Plymouth Company granted a portion of its territory to its President, Robert, Earl of Warwick, and as the description in this grant is a curious one, I will give it in full: "All that part of New England in America which lies and extends itself from a river, there called Narragansett River, the

space of forty leagues upon a straight line near the seashore towards southwest, west and by south, or west as the coast lieth, towards Virginia, accounting three English miles to the league, all and singular the lands and hereditaments whatsoever, lying and being within the bounds afore said, north and south in latitude and breadth, and in length and longitude, and within all the breadth aforesaid, throughout all the main lands there from the Western Ocean to the South Seas." This description, Col. Whittlesey writes, formed the legal puzzle of a century and a half, as to what lands it included and what it did not, March 19, 1631, Earl Warwick conveyed the same land "more or less" to the founders of the State of Connecticut, by grant termed the "Patent of Connecticut." This grant covered most of Pennsylvania, but Connecticut was finally ousted from her claims there, and the western boundary of the former State was finally established as it now is by a commission of the United States in 1785 and 1786, who set a stone monument where the line came to the lake shore. The State of Connecticut, to strengthen its political rights, had obtained from Charles II., April 23, 1662, a confirmatory Charter by which her north boundary was fixed as the parallel of 42 degrees and 2 minutes north latitude, and her south boundary was finally fixed as the 41st parallel.

By a deed to the United States, of September 13, 1776, Connecticut relinquished all claim to her western territory, *excepting and reserving* all that part between her north and south boundaries, as aforesaid. bounded east by the west line of Pennsylvania, and west by a meridian line distant 120 statute miles therefrom ; hence this tract has since then been called "The Connecticut Western Reserve," and popularly the "Western Reserve," and still shorter the "Reserve," by which latter name I shall allude to it hereafter. The political status of the Reserve was in dispute between Connecticut and the United States until 1800, when the United States confirmed Connecticut's title to the soil of the tract, and Connecticut released all her claims to political authority over it. In May, 1792, Connecticut made a grant of one-half million acres, exclusive of the islands in Lake Erie, from off the west end of the Reserve, to those of her citizens who had suffered loss, chiefly by fire, from the depredations of the British in the Revolution ; hence these lands are called the "Fire Lands." On the 5th of September, 1795, she deeded for the sum of $1,200,000, three million acres from off the east end of the Reserve to a stock company of 57 individuals formed at Hartford, and known as the "Connecticut Land Company," and it is from the deeds to its members that Abstracts of Title to lands in this county are dated. At that time Lake Erie was supposed to lie nearly east and west, and so it was thought there must be an immense tract between the Land Company's land and the "Fire Lands." This was called "the Excess," and a company called the "Excess Company" bought the title to it from the State, but this "excess" turned out to be as mythical as the "Great South Sea," as instead of an excess there is a deficiency, the actual area of the Land Company's tract, including the islands in the lake, being about 2,837,100 acres, as figured after all surveys and sales had been made, by the late Leonard Case, Sr., who was agent here for the State of Connecticut for the sale of some lands reverting to it. The same day it received its deeds from the State the

Land Company deeded the whole tract in trust to three trustees, John Morgan, John Caldwell and Jonathan Brace, and it is by deeds from these trustees that title to nearly all the land in the Reserve has been obtained.

The Cuyahoga River had for many years before this formed, together with the "Portage Path" and the Muskingum River, an important boundary line between Indian tribes, and so recognized by the whites in treaties with them, the "Portage Path," as is generally known, being an old Indian trail between seven and eight miles long, connecting the Cuyahoga River where it begins to bend to the northeast, about thirty-five miles from its mouth, with the headwaters of the Tuscarawas branch of the Muskingum. and over which the Indians carried or made a "portage" of their canoes. In 1796 the Land Company determined to extinguish the Indian title on their tract east of the Cuyahoga and the "Portage," and to survey this part into townships. The plan decided on. and which was carried out, was to make these townships five miles square, or nearly so. by running meridian lines every five miles west of Pennsylvania, and parallels of latitude every five miles north from their south boundary line.

The townships bounded by these lines were designated by both "range" and "tier" numbers, the first numbering west from Pennsylvania and the second north from the 41st parallel. Those bounding on the lake formed irregular or fractional townships. To carry out this scheme the Land Company, in 1796, sent out surveyors, with their assistants, numbering together 43, all under the direction of General Moses Cleaveland, of Canterbury, Wyndham County, Connecticut, who was appointed general agent of the company. As is generally known, it is from him that our city is named, after dropping out the first "a" in his name, originally through inadvertence. He was also one of the directors of the company, having $32,600 stock in it. Augustus Porter, of Salisbury, Conn., was made principal surveyor, and Seth Pease, of Suffield, Conn., second, he being also the astronomer and mathematician of the party.

The other surveyors were John Milton Holley, Richard M. Stoddard and Moses Warren, Jr., all of Connecticut. Augustus Porter had been engaged since 1789 in surveys in Western New York, on what is called the "Holland Purchase." The whole party proceeded to Buffalo, where General Cleaveland made a treaty with the Indian chiefs, and obtained from them a grant of the land east of the Cuyahoga and the Portage. It is related in the journal of Seth Pease that the Indians received, besides goods and two beef cattle, one hundred gallons of whiskey, "fire-water" then, as now, forming an important element in our relations with "the noble red man."

The whole party then proceeded along Lake Erie, and on the 4th of July, 1796, reached the western boundary of Pennsylvania, and discovered the monument set near the shore on said line by the commission of 1785, and which they used as the starting point of their surveys in "New Connecticut." They celebrated the "Fourth" in a patriotic manner at the mouth of Conneaut Creek, which is less than two miles within the State of Ohio, with speeches, gunpowder and "toasts," consuming in the latter, according to Cleaveland's diary, "several pails of grog." The party, including teamsters, cooks, etc., numbered fifty-two.

I might, did not the limits of this paper forbid, give some account of the particulars of the township surveys then commenced, and also make some quotations from the biographical sketches of the leading surveyors given by Colonel Whittlesey, but will only quote his general remark that the qualifications necessary to success in surveying these Western wilds were such that those engaged were generally the most prominent men on the frontier.

The southeast corner of the Reserve was fixed at 68 miles from the lake. The first four range lines west of Pennsylvania were the only ones run up in 1796. and nearly all the township lines east of the Cuyahoga and north of the 6th or 30-mile parallel were completed in 1796. The lines were run with reference to the true meridian, obtained by observations of the polar star when possible. The variation of the needle at the mouth of the Cuyahoga was 1 degree and 30 minutes east. The variation at this harbor in 1880 observed by the Government engineers was 1° 38′ 5″ west according to Col. Whittlesey. There is in the rooms of the Western Reserve Historical Society in this city, a collection of early maps of Cleveland and the Reserve, among them a map of the Reserve made in 1797 by Seth Pease, which is very well executed. It measures about 33 inches by 20 inches. Pease was noted for his ability as a draughtsman and penman. This map shows the land west of the Cuyahoga, marked "Unsurveyed and subject to Indian claims." The township of Cleveland is shown as lying in the 12th range and west of the 7th and 8th tiers of townships, being bounded East by "Euclid" and what is now Warrensville townships and north and west by the lake and river, being an irregular and large township, marked as containing 25,242 acres. It is known in deeds as the 7th township in the 12th range. Out of this original township of "Cleaveland" have since been formed. "Cleveland," "Newburgh" and more than half of "East Cleveland" townships, the line between the two latter townships being the line between the 7th and 8th tiers and strikes Willson avenue at Cedar avenue. While the remaining parties were engaged on these township surveys, Porter had started from the Pennsylvania line to traverse the lake shore west and to fix the west line of the Reserve at the point where the sum of the departure of his coursers should equal 120 miles. This he did, though west of the Cuyahoga he had to take the risk of running in Indian territory. This west line strikes the lake near the middle of Sandusky Bay. The east line of the "Fire Lands" strikes a short distance east of the mouth of the Vermillion River. I submit a rough outline map of the Reserve, merely to show the manner of its sub-division into townships, the present counties embraced in it, some of the important rivers, and the "Fire Lands," and "Portage Path." (See Map No. 1.)

Leaving the parties engaged on the township lines, General Cleaveland proceeded to the mouth of the Cuyahoga. which he reached July 22, 1796. The party landed near the foot of Union lane, and soon after built a store-house and cabin for the surveyors near a spring on the side hill south of St. Clair street and west of Union lane, now Spring street.

Porter and party, after completing the traverse of the lake shore, returned to this point, and all the other parties, after surveying most of the townships north of the sixth parallel. reached here at different times in

MAP OF THE "WESTERN RESERVE"

September. On the 16th of September, 1796, was begun the first survey of our city. On the 22d, Holley, Shepard and Spafford left here to run out the eastern part of "Cleaveland" township into what are called the "100 Acre Lots." they being generally 25 chains east and west and 40 chains north and south, "Cleaveland" being one of six townships that the directors had decided to allot and sell for the general benefit of the company. The numbers of these lots run from 267 to 486, and why the numbers so begin instead of with No. 1 seems to be "one of the things no fellow can find out." Lands in "Newburgh" and "East Cleveland" townships have since been sold and allotted with reference to these 100 Acre Lots, and I shall not again refer to the survey of them. To return to the survey of the city.

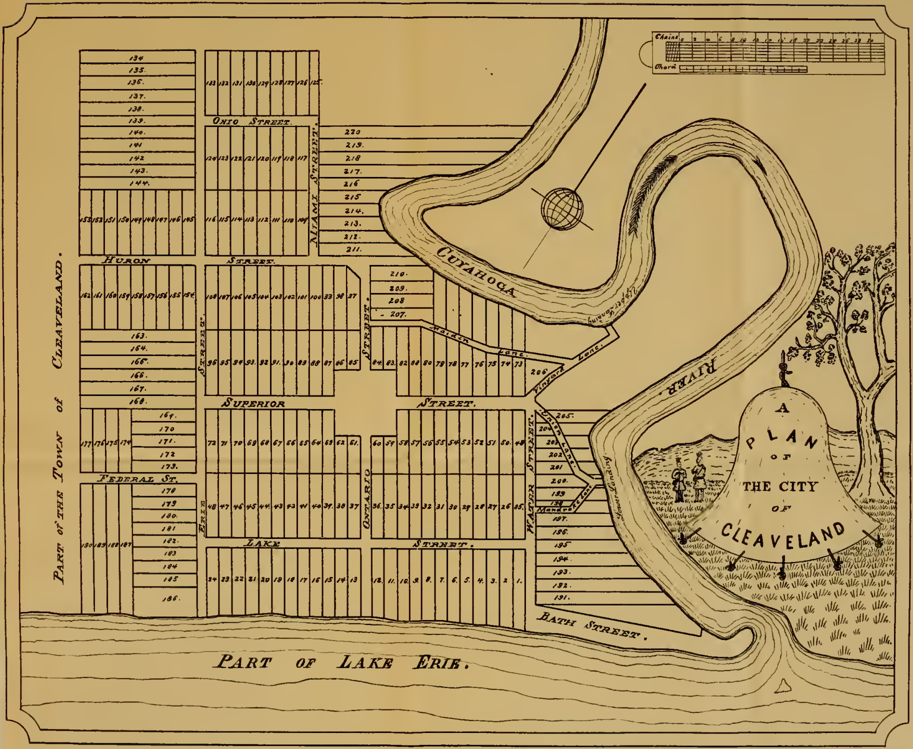
There is in the office of the City Civil Engineer, where I am employed, on the first page of a volume entitled "Maps and Profiles, Vol. 1," a map entitled "A Plan of the City of Cleaveland," and a careful copy of which is presented herewith (see Map No. 2).

As may be seen, there is in the lower right-hand corner a rather quaint picture, representing two Indians, one with a gun, standing on a plain. To their left is a tent, on which is painted the above title, and to its left a tree. In the back ground are some hills. This picture, in the said record, is in colors. In the left part is the map proper, showing the Cuyahoga and Lake Erie, and the original streets and lots of the "city" as it was ambitiously entitled at the very outset. Following this map in the volume above mentioned, is the description of these streets and lots, entitled "The Survey of the City of Cleveland, begun September the 16th, 1796 (by Seth Pease), situated on the east side of Cuyahoga River, at its mouth, containing 220 lots," following which is a statement by I. N. Pillsbury, then City Civil Engineer, that the foregoing map, minutes and descriptions are accurate transcripts of a copy made in 1842 by said Pillsbury, from the original map and minutes of the survey of Cleveland, made in 1796 by Seth Pease. Following is a statement of Leonard Case, Sr., Esq., dated February 6, 1843, that he carefully compared the said copy of Pillsbury's with the original map and minutes (which were recognized by the Hon. Calvin Pease as being in the handwriting of his brother Seth), and that the same was "as near a fac-simile copy of the original as can usually be made by ordinary writers." Following is the certificate of Ralph Granger, Esq., of Fairport, O., a nephew of Seth Pease, acknowledged in Cleveland, February 21, 1843. Mr. Granger states that he also compared Pillsbury's copy with the original, which is a small manuscript, entitled "Field Notes made on the Connecticut Western Reserve, by Seth Pease." He refers to the map as "bearing the figure of a bell," evidently meaning the tent or wigwam, as I take it, next to the Indians in the picture. Thus it will be seen the city has without doubt a very careful copy of Seth Pease's map and minutes of the original survey, and the only one, so far as I know, now in the city. Where these original minutes and map now are I am unable to say. They are not in possession of the Historical Society nor of the heirs of Leonard Case. Judge Ranney informed me lately that he remembered well the map being in possession of Leonard Case, Sr., who guarded it jealously, the Judge having with difficulty obtained it for a short time one day to use in some legal matter. This map was not the earliest one made, however. There is, on the first page of the Histori-

SETH PEASE'S

MAP.

1796.



I.M. PILLSBURY. C.C.E. JAN. 5TH 1855.

cal Society's Volume of Old Maps, a map that is probably the first one made of the "City." It was found among the papers of J. Milton Holley, by his son, Governor Alexander H. Holley, of Connecticut, and sent by him to Colonel Whittlesey, who has a reduced copy of it in his "Early History of Cleveland," and who writes of it as follows: "It is indorsed in the handwriting of Amos Spafford, 'Original Plan of the Town and Village of Cleveland, Ohio, Oct. 1st, 1796.'

"The sheet is formed by pasting several sheets and parts of sheets of foolscap together, evidently extemporized in the field. It was the first rough sketch used by the surveyors before their return to the east." Further on, he says: "After the return of the surveyors" [that is, to Connecticut, they leaving here October 17, 1796.—S. J. B.] "regular field notes of the surveys of the city were made out by Seth Pease, which are regarded as the official returns. With these notes is a map, styled on the face of it, 'Plan of the City of Cleaveland, 1796,' which is substantially the same as the one here given" [that is, the one printed in his book.—S. J. B.] "The river bluffs are slightly different, and the sand pit at the mouth is longer." [Col. Whittlesey, by this latter map, undoubtedly refers to the map of which I have presented a copy, but the date "1796," is not on the title.—S. J. B.] Again he writes: "Several copies of the plat were made during the winter of 1796-97, for the use of the company, but it was never engraved. About the year 1816, soon after the organization of the village corporation, when some new streets were thought to be necessary, the authorized book of field notes, with its miniature plan, was brought here by James Root, Esq., brother to Ephraim Root, the secretary of the company.

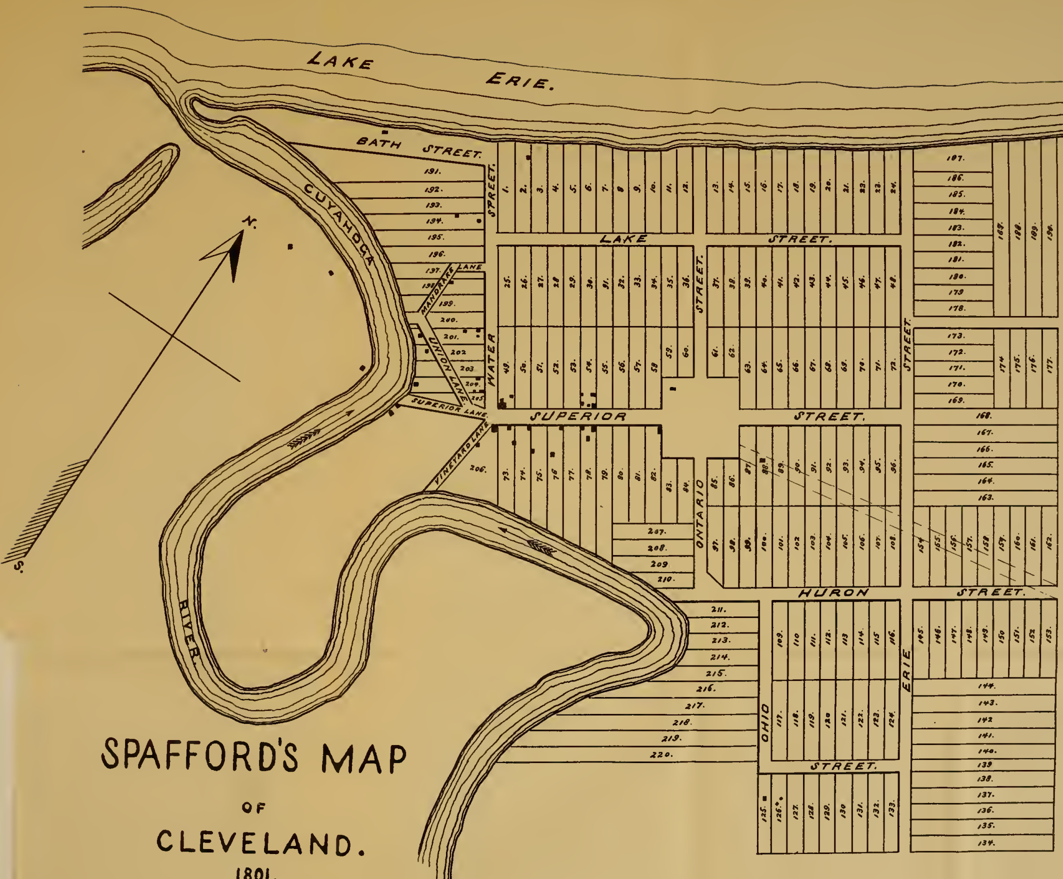
"This book remained here until about the year 1856, since when, not being in official custody, it has disappeared. There is not now upon the Western Reserve a collection of the papers, maps, field books and proceedings of the company, from whom all our land titles are derived. A part of the field notes by Pease, Holley and Warren are in my possession." It was undoubtedly from these minutes and map so brought here by James Root that Pillsbury made his copies.

It is generally understood, I believe, that Seth Pease made the original survey of "Cleaveland," as well as recorded the minutes and made the map of it, but in his biographical sketch of Augustus Porter. Colonel Whittlesey gives extracts from a letter of Porter to the late Judge Barr, of this city, dated at Niagara Falls, January 10, 1843, written in answer to a request for information which seem to upset this idea. Porter writes: "Had I all my original papers connected with the subject above named, such as my journal, original field notes of surveys, taken on the ground, calculations on contents, geographical remarks, of persons employed, etc., I should be able to give you such information, and it would give me much pleasure to do so. But unfortunately all these documents were lost in my dwelling-house at this place, destroyed in 1813 by British troops." (Porter, in this letter, it is remarked by Col. Whittlesey, writes entirely from memory of what occurred forty-seven years before, and therefore may be slightly wrong in some of his statements).

Porter says, further on in this letter: "Having returned from Sandusky

Bay to Cuyahoga, I remained there some time—perhaps two or three weeks—and surveyed the outlines of a piece of land designed for the town. Its dimensions I do not recollect—probably equal to about a mile square, bounding west on the river and north on the lake. I made a plat of this ground and laid it off into streets and lots. Most or all the streets I surveyed myself, when I left it in charge of Mr. Holley to complete the survey of the lots." This certainly indicates that Pease did not make the survey, as supposed, but it is generally known as his, and so I will allude to it; undoubtedly he assisted in making it. Colonel Whittlesey says that in those of his journals he has found, Holley says nothing about working on these "two-acre" lots, as stated by Porter.

In 1801 Amos Spafford made a re-survey of the streets and lanes of Pease's survey, and made a new map of the so-called "city," which, with the description of the streets, lanes and "Square," was recorded in the Trumbull County Records at Warren, O., February 15, 1802, in Vol. A, page 100. Colonel Whittlesey says this was done in obedience to a statute, and the Land Company and its grantees became bound by it. Trumbull County, by the way, was erected by the United States, July 10, 1800, and embraced exactly the whole of the "Reserve" and islands, with county seat at Warren. This record, however, is informal, being without the signature of Spafford or of any acknowledgment or indorsement of any member or officer of the Land Company. A copy of this map and description was entered in the Records of Cuhahoga County, in Vol. A, page 482, etc., of Deeds, Nov. 22, 1814, and Dec. 26, 1856, transcribed into Vol. 2, page 24, of Maps. A copy of this map and description was entered in the City Engineer's Record, before mentioned, by I. N. Pillsbury. The descriptions are entitled "Minutes of the Survey of the Outlines, Roads, Lands and Square of the City of Cleveland, as Surveyed for the Connecticut Land Company, in the Year 1796, by Augustus Porter. Said Minutes Retaken by Amos Spafford, Surveyor, Nov. 6, 1801." At the end of the description of streets, etc., is written: "For the particular numbers and boundaries of each lot, reference is to be had to the field notes and map in the Register's office in the county of Trumbull, or in the city of Cleveland." This leaves it somewhat doubtful to me whether by the "field notes and map" last-mentioned, reference is made to those of Seth Pease or to other new ones made by Spafford, but most likely to those of Pease; but the latter, I am satisfied, are not on record in Warren, or they would have been copied into our County Records long ago, or have become known to some of our Examiners of Titles, and they certainly are not in the County Records here, and, so far as I know, there are no copies in this city besides those in the Engineer's office. Certain it is, that for particular description of the two-acre lots, reference must be had to Pease's notes. I append a copy of Spafford's map, from the Engineer's Record (see Map No. 3). It will be noticed that there are buildings shown on this map in black. These, it is said, represent all the buildings standing in 1814, and were put on by Alfred Kelley, Esq., when the map was recorded here. The lines of Euclid avenue, from the "Square" to the end of Huron street, are also shown, but they were probably put on about the same time, as Euclid avenue was laid out as shown, in October, 1815, by the Trustees of Cleaveland Village. Spafford's map does not differ materially



SPAFFORD'S MAP OF CLEVELAND. 1801.

from Pease's, except that in it "Maiden lane," shown on Pease's, and which occupied about the location of the present Michigan street, is not shown at all, and that Vineyard and Union lanes are straightened, and Superior lane is opened from Water street to the river. Besides these lanes, there were ten original streets, each six rods or ninety-nine feet wide, except Bath (now Front) street, which was irregular, and Superior street, which is 8 rods or 132 feet. Those parallel to Lake Erie are Lake, Federal, Superior, Huron and Ohio; their course is north 56° east. Those at right angles to them, or north 34° west, are Water, Ontario, Erie and Miami. This latter is shown as part of "Ohio" street on Spafford's map, but the name "Miami," as given by Pease, finally obtained, but a part is now called Sheriff street and the remainder Ontario street. The lots generally, except those which are irregular by reason of bounding on the lake or river, are two chains wide by ten chains deep, containing therefore, two acres. The old bed of the river is also shown on Spafford's and not on Pease's. I notice that on Dare's map of Cleveland, published in 1868, a copy of Pease's map is erroneously entitled "Spafford's." I also notice some errors in the description of streets accompanying Spafford's map. For instance, it says Superior street is 50½ chains long from the west line of Water to west line of Erie street. It should be 51 chains. Also that the "Public Square" contains 10 acres, should be 9½ acres, it being 9½ chains east and west, and 10 chains north and south, by reason of Superior street being ½ chain wider than Ontario street. (The east line of the "two-acre lots" or Original Town is now the centre of Brownell street, and of Canfield street north of St. Clair street, and the south line is parallel with and 112½ feet south of Parkman street, being the south line of "Parkman lane and same produced westerly.") Spafford's description says the length of the south line of the "city" is 38½ chains; it should be 37. Also, that it is 10½ chains from said south line to north line of Ohio street; it should be 11½. Spafford's makes the course of the south line of Bath street south 66° west; Pease's south 64° west. But this is probably due to an intentional change of direction. Pease's descriptions of streets and of lots tally very closely with each other, except that by the first he makes Lake and Superior streets 20 chains apart and parallel, and by the lot depths given they are 20.12 chains apart on the east line of Water, and 20.03 chains on the west line of Erie street. Also Lake street, south line, is 49.54 chains long, by the lot fronts, from east line of Water to west line of Erie street, instead of 49.5 chains, as by street description.

In 1797 the surveyors returned to the Reserve, but neither Cleaveland, Porter nor Holley came with them. Seth Pease was chief surveyor, with eight assistant surveyors, among them being Warren, Stoddard, Spafford, Shepard and Amzi Atwater of the 1796 party, the latter having then been a surveyor's assistant, however. In this year were surveyed the "Cleveland Ten-Acre Lots," so called, extending from the two-acre to the 100-acre lots, or from Brownell street to Willson avenue. In the City Engineer's Record, before mentioned is a copy of the minutes of this survey (which was made principally by Moses Warren, Jr.), taken by Pillsbury, and noted as "extracted from the private notes of Leonard Case." There is also a map of these lots, drawn to a scale of 15

chains to the inch, accompanying, which bears the statement: "Drawn from the Original Notes, January 27, 1855: J. N. Pillsbury, C. E." It does not seem that there was any map of the survey of these lots made by Warren at the time of his survey. I lately compared the Engineer's Record with what I supposed to be these private notes of Leonard Case, referred to by Pillsbury, and which are in the handwriting of Mr. Case, Sr., and accompany a small map of the lots, also drawn by him, and find that while they agree generally, there are verbal differences and entire omissions of certain courses, etc., in Mr. Case's notes; so I think Mr. Case must have previously had another copy of the Original Notes from which Mr. Pillsbury made his. Up to a very recent time there was not in this county or elsewhere, that I can learn, any public record of the survey or laying out of these lots, forming such a large part of the most valuable portion of our city, but March 27, 1879, Mr. Jno. L. Culley, one of our members, entered in Vol. 11, page 32 of the County Recorder's maps, a map and field notes of these lots both of which I find to be the same as those in the Engineer's Record and he adds the statement: "The above map and field notes of 'Cleveland Ten-Acre Lots' are a correct copy of the same as they are to be found in the office of Leonard Case, of this city; the map and notes in said Case's possession are supposed to be the only authentic ones in existence."

I cannot find that the Case heirs have any map or notes of these lots other than those of Mr. Case, Sr., which, as I said before, are somewhat different from the Engineer's Record. I lately discovered in the Western Reserve Historical Society Rooms an authentic copy of Warren's notes. In a small volume, about 4 by 6 inches, entitled "Field Notes, 1797," at the beginning of the Sixth "Book," so called, of this volume, is the following title, "Traverse of the Portage from Cuyahoga to Tuskarawas, part of the second parallel and *Survey of the ten-acre Lots in the town of Cleaveland by Moses Warren, Jr.*," and below is written, "Transcribed by the late Genl. S. D. Harris, surveyor, Ravenna, Ohio, for me. Presented by

(Signed) CHAS. WHITTLESEY."

Then, after the copy of the notes of the other surveys mentioned in the title, comes that of the notes of the survey of these lots, closing with the words, "Extracted from the original notes and compared by Moses Warren, Jr." (which words are evidently part of the original). Then follows the statement: "I certify the foregoing to be a correct copy of the original on file in my office.

(Signed) SAMUEL D. HARRIS,

"County Surveyor of Portage County, August 16, A. D. 1845.

"NOTE.—In the foregoing copy I have been careful to preserve the spelling as in the original. (Signed) S. D. HARRIS."

The whole of Mr. Harris' copy is written in a clear and neat hand.

I till lately supposed that the notes of Leonard Case, Sr. were the authentic ones, but this, taken together with what I found said notes to be, throws a different light on it. It is curious, but I do not find that Col. Whittlesey in his published writings mentions this copy as having been made for him, although I know of his informing a gentleman of its existence quite recently. I took an exact copy of this copy by Mr. Harris

and found it to compare very closely with Pillsbury's, the differences being merely verbal except that in the former the north line of Euclid avenue is said to be 65 links longer than the south side, and in the latter 62 links, and the former would correctly make the front on St. Clair street of lot 131—14.06 chains instead of 14.6 chains as in Pillsbury's, and also give the depth of the lots on the south side of Woodland avenue as 20 chains, which is omitted in Pillsbury's copy. I have corrected Pillsbury's copy in the Engineer's Record accordingly, and that recorded at the Court House should also be corrected.

From the fact of Mr. Harris copying directly from the original notes in his possession, and having, as he states, been careful to copy even the mode of spelling, I am satisfied that this is the only well authenticated copy of the notes now in Cuyahoga County. Having now settled this question, let us inspect the notes themselves.

They begin under date of August 20, 1797, and describe as this day's work the laying out of what is now Euclid avenue from the east end of Huron street to Willson avenue, the centre line of the latter being the dividing line between these ten acre lots and the 100 acre lots, and being a north and south line.

As the next day's work in this survey is dated "Monday, August 21st," it follows that the survey was begun on Sunday, the surveyors evidently not having the fear of the "Connecticut Blue Laws" before their eyes. There were three roads laid out by this survey, called the "North," "Centre" and "South" highways, and being now called St. Clair street, Euclid avenue and Woodland avenue respectively, each 99 feet wide, and their respective courses being N. 58° E., N. 82° E., and S. 74° E., all extending from the line of the city as laid out by Pease, to the line of the 100-acre lots, the first connecting with Federal street, the second with Huron, and the third with Erie street of Pease's plot. Warren erroneously terms "Federal" (now St. Clair) street "Lake" street in these notes. Midway between the "North" and "Centre" and "Centre" and "South" highways were run lines, also from the "city" line to the 100-acre-lot line, and which form the rear boundaries of the lots, which were laid out 5 chains wide (except those adjacent to the city line, and the 100-acre-lot line), their side lines running back to these rear division lines, at right angles with the highways. Thus, the streets and rear lines of lots all radiate from the original town, each making an angle of 12° with the next adjacent north or south and the side lines of the lots are parallel and make angles of 24° deflection at the rear lines, the whole resembling a fan or a section of a spider's web. As stated by Col. Whittlesey, the object of laying out the lots and streets in this fashion was not, as has been supposed by some, from a preference for such a geometrical plan, but to equalize the lots as to value. The fronts being the same, and the value decreasing according to the distance from the "city," this decrease was to be compensated by the increased depth of the lots. I present a map (see No. 4) of the survey, drawn from the notes, and which, as well as the copies of Pease's and Spafford's maps presented, was made for me by Mr. Otto Dercum, of the City Civil Engineer's Office. Payne avenue has been opened along the dividing line between the St. Clair street and Euclid avenue lots, and Garden street on

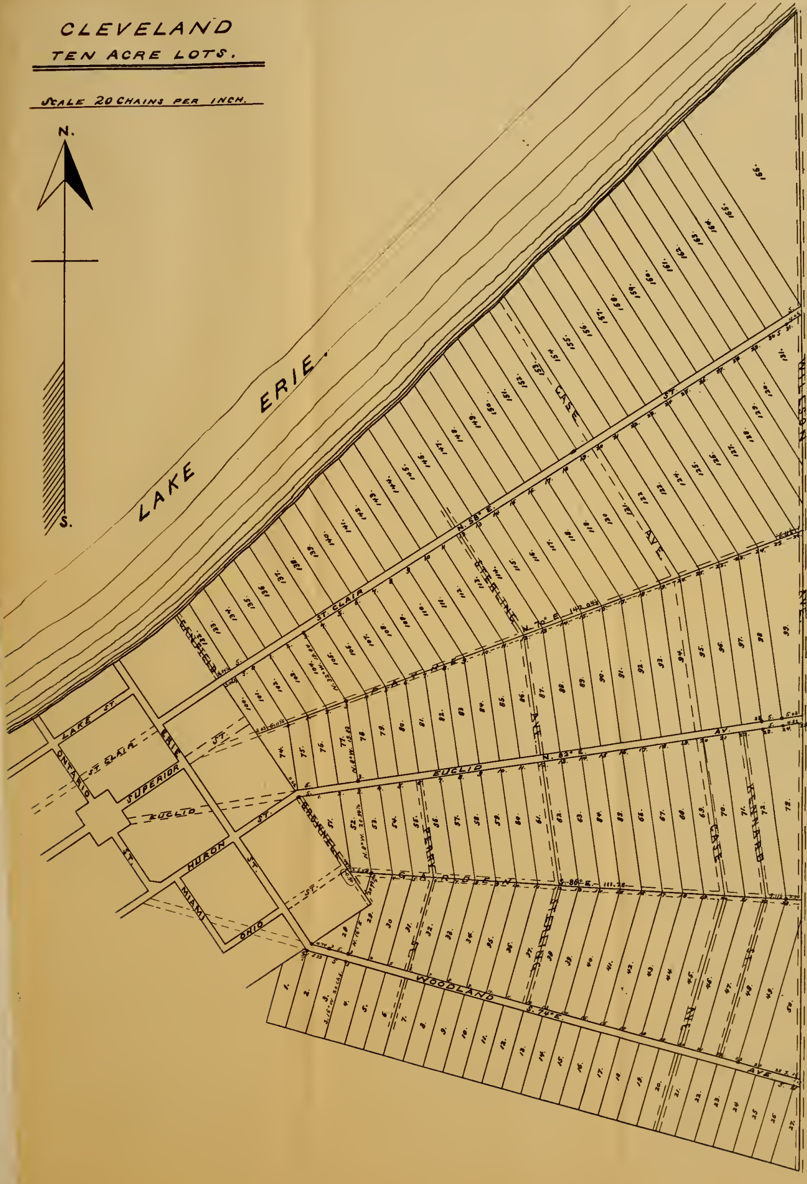
that between the Euclid avenue and the Woodland avenue lots. Perry street, Sterling avenue, Case avenue and Kennard street have also been opened upon the side lines of lots, as shown in dotted lines on map here presented. The lots fronting on the south side of Woodland avenue are the only ones that actually contain 10 acres each, being 5 chains front and 20 chains deep, and the reason the rear is parallel to the front of this tier is probably on account of the Kingsbury Run ravine lying along the rear line. The other lots from the very nature of their boundaries, differ widely in area, some having less than 10 acres, some as high as 35 or 40 acres, and one, No. 166, about 100 acres. The numbers of the lots, as will be seen, begin at the west end of the south tier and run east, then begin again with the next consecutive number at the west lot of the next tier north, and so on. When these numbers were assigned is something of a question, probably in 1801, in which year the Land Company divided the unsold portions of the six townships, including "Cleaveland," which had been reserved for the benefit of the company, into tracts of 1,000 acres each. The whole $1,200,000 of stock was divided into 90 drafts, each representing $13,333.33⅓, and the tracts were drawn in a lottery by the holders of these drafts. To equalize these tracts as to value, certain of the 2-acre and 10-acre lots were added to them. There is in the Historical Society maps a very old map of "Cleaveland Township," showing the 2-acre, the 10-acre and the 100-acre lots, the latter parceled off into 16 1,000-acre tracts, and the numbers on the 10-acre lots are given just as they stand to-day; and a table is added to the map showing what lots were added to what tracts, and to whom they went, and this, so far as I know, is where the numbers were assigned.

Warren set square posts for the front corners of all the lots. The figures shown at the lot corners on the map are the numbers of his tallies or each 5-chain measurement from his beginning point, which are marked with ciphers.

His descriptions of the highways sound queerly enough at the present day. Of the "Centre highway" he says: "The land admits of an excellent highway to the middle of No. 24, and then of a good cartway north of the swamp to the 100-acre lots; the soil is preferable to that of the city, timber oak, hickory, chestnut, box." This is slightly different from the Euclid avenue of our day, with its block-stone pavement, electric lights, elegant residences, &c. Of Woodland avenue he says: "The land admits of an excellent highway, but is not as good for grass as that of the centre laid out yesterday." Of St. Clair street he says; "In the beginning of the 3d and 20th tallies are small brooks; the land is swampy and scalded, but hard clay bottom, will require causewaying to be good road, but can be passed as it is, and is good land for grass."

I will now give some figures to show how Warren's measurements compare with modern measurements.

As is generally the case in old surveys, there is found a considerable surplus or excess above the recorded fronts of these lots. This is due largely from the tendency of a chain in constant use, as it was in these old surveys, to elongate from the opening and wearing of the rings connecting its links. Considering, however, that these early surveys were made with the primitive compass and iron chain, and through a thickly wooded


CLEVELAND
TEN ACRE LOTS.
SCALE 20 CHAINS PER INCH.
N.
S.
LAKE ERIE.
ST. CLAIR ST.
EUCLID AV.
WOODLAND AVE
WILSON AVE.
STERLING AVE
CASE AVE
KENNARD ST
PERRY ST
ERIE ST.
HURON ST.
MIAMI
OHIO
ONTARIO
LAKE ST.
SUPERIOR
ST. CLAIR
EUCLID
N. 58° E.
N. 70° E.
N. 82° E.
S. 86° E.
S. 74° E.

country, it must be conceded that the measurements both of the 10-acre and the 2-acre lots show a notable uniformity of surplus, showing that they were taken with considerable care.

In 1855 a survey of the 10-acre lots from the 2-acre-lot line to Willson avenue, and from Euclid avenue to St. Clair street, was made under G. A. Hyde, city engineer, by Charles Hermany, assistant, and from the results of his survey I will give some comparisons. At that time the east line of the 2-acre lots, or centre of Canfield street and Brownell street, was defined by two stone monuments, one on the south line of St. Clair street and one on the south line of Euclid avenue (and Huron street), and the east line of the 10-acre lots, or centre of Willson avenue, was also defined by stones on the south lines of St. Clair street and Euclid avenue. These I will term the "end monuments." There was also a stone on the south line of St. Clair street and in the centre of Case avenue; also one on north line of St. Clair and centre of Sterling avenue; also stones on the south line of Euclid and centres of Perry, Sterling, Case and Kennard. There is no record as to who originally set these monuments, but I think likely they were set partly by Ahaz Merchant, who was county surveyor here more than fifty years ago, and partly by his son Aaron, also county surveyor after his father, both of whom set many monuments that are not recorded. John Shier, of whom I will speak again, may have set the ones on the 2-acre-lot boundary and the one at Perry st. However that may be, these stones have long been regarded as correct by surveyors. I have never heard of their being disputed. There were no stones set by Warren—only posts at the lot corners—and undoubtedly these stones were set according to the location of these posts. They are all now in existence, except the ones at Canfield street and Case avenue, which have been lost. Hermany's measurements, it is worthy of note, are recorded as having been made with a steel tape. His measurement on St. Clair street, between the end monuments, was 11,126.3 feet. Warren's was 11,056.65; surplus 69.65 feet, equal to about 0.63 feet per 100 feet, 0.416 feet per chain and 2.08 feet per lot, making the lots 332.08 feet wide, instead of 330 feet by Warren. A straight line between the end monuments in St. Clair street was 97.05 feet from the stone at Sterling, instead of 99 feet as it should be, and was 1.51 feet north of the stone at Case avenue. This latter stone was found to be only 0.17 feet, or two inches west of where a proportionate distribution of this surplus between end stones would bring it. On Euclid avenue, between end monuments, Hermany's measurement was 8,296.38 feet; by Warren it was 8,238.05; surplus, 58.33 feet, equal to 0.708 feet per 100 feet, 0.467 feet per chain and 2.355 feet per lot, making their front 332.355 feet, instead of 330 feet. A straight line between the end stones made the one at Perry 4.27 feet south, the one at Sterling 1.29 feet south, the one at Case 0.92 feet south, and the one at Kennard 0.08 feet south. I found written by L. Case, Sr., on the back of his map of the 10-acre lots, a statement of the following measurements made by I. N. Pillsbury, May 30, 1860:

On south line St. Clair from the 2-acre to the 100-acre lots, 11,124.2 feet, being 2.1 feet less than Hermany's, and making a difference of 0.02 feet, or about ¼-inch less surplus in each 100 feet. On Euclid south line, be-

tween same lines, he makes 8,294.67 feet, being 1.71 feet less than Hermany's, showing same rate of difference as on St. Clair.

I have no other direct measurement taken at one time between the end stones in Euclid of later date than this of Pillsbury; but from careful steel-tape measurements, taken at various times on Euclid avenue since 1870 by the late Assistant City Engineer C. A. Walter, and myself, and connecting them by the angles turned, with these end stones, I find the distance to be 8,293.27 feet, being 1.40 feet less than Pillsbury's and 3.11 feet less than Hermany's, making the surplus 0.670 feet per 100 feet and 2.211 per lot = 0.144 feet less than by Hermany. I have no other connected careful measurements between end stones on St. Clair street; neither have I any very close measurements on Woodland avenue, but taking the recorded frontages in sub-divisions on the north line of this avenue, plus the widths of streets, we get from the east line of Erie to the centre of Willson a total of 8,359.46 feet (which may, however, be considerably short, as there is generally a surplus in the allotments). Warren's measurement = 125.81 chains = 8,303.46 feet = 56 feet surplus = 0.445 feet per chain, 0.674 feet per 100 feet, and 2.225 feet per lot, being almost exactly the same as on Euclid avenue. A straight line run in 1869 by the city engineers, at the time Woodland avenue was paved, between monuments on said north line, one on east line of Erie and the other in centre of Willson, shows that said north line is pretty straight, monuments set to define it at following streets being as follows with reference to said straight line: At Vine street, 0.25 feet N.; at Chapel street, 0.32 feet N.; at Greenwood, 0.49 feet N.; at Forest, 0.33 feet N.; at Case avenue, 0.10 feet N., and at Kennard street, 0.17 feet S. Only one monument on the south line of the avenue was measured to—that at Humboldt street; it was 97.92 feet distant, being 1.08 feet too far north.

The rate of surplus in the 2-acre lots seems to be somewhat less than that in the 10-acre lots—at least on most streets. Take Superior street, for instance. I found among Leonard Case, Sr.'s, papers a copy of a survey made by Messrs. Pillsbury and Whitelaw in 1859.

They make the distance in centre of Superior, from stone on east line of Square to west line of Erie street, 1,327.67 feet. Seth Pease's distance is 20 chains or 1,320 feet; surplus, 7.67 feet=0.383 feet per chain.

Pillsbury's measurement in 1852 in centre of Lake street, between stones in centre of Water and Erie streets, is 3,385.67 feet. Pease's distance is 51.04 chains, or 3,368.64 feet; surplus=17.03 feet or 0.334 feet per chain. This measurement of Pillsbury's is almost exactly the same as measured in Superior street, from centre Water to centre Erie, by C. A. Walter and myself, ours being 3,385.86 feet. By Pease it is 51 chains, or 3,366 feet; surplus=19.86 feet=0.389 feet per chain; the distance from the stone Mr. Walter set in the centre of Water street to the one on east line of the "Square" being 2,008.77 feet steel-tape measurement, and from thence to the centre of Erie street 1,376.9 feet, measured with a chain to nearest tenth, but which is only 0.23 feet longer than Messrs. Pillsbury and Whitelaw's. The distance by C. A. Walter and myself in centre St. Clair street, from stone centre Erie street to stone on east line 2-acre lots, is 1,241.31 feet. Pease's distance is 18.75 chains or 1,237.5 feet, making surplus 0.203 feet per chain. Walter & Co.'s measurement in

centre Brownell street, or east line of 2-acre lots, from stone on south line of Huron street to stone on south line of 2-acre lots, is 2,093.12 feet. By Pease it is 31½ chains=2,079 feet; surplus=14.12 feet=0.448 foot per chain. The sum of various measurements in centre Erie street, from stone centre Superior street to south line of 2-acre lots, mostly by Hermany in 1855, is 3,586 feet. By Pease it is 54 chains or 3,564 feet; surplus=22 feet=0.407 foot per chain. Of course all these rates of surplus are only general averages, using extreme points. In actual surveying the rate may be found to be somewhat more or less by using intermediate stones controlling lot or street lines.

It is rare to find an old street laid out perfectly straight, as recorded, and all of our original streets are more or less crooked, due to the haste, difficulties of field work and imperfect instruments of original surveyors. I might show many more comparisons of distance, &c., but will let what I have given suffice. I have spoken of stone monuments in the streets of the original town. These streets, it is understood, were nearly all so defined by Mr. John Shier, who was appointed City Surveyor and Engineer May 11, 1836, by the City Council, on motion of Mr. W. V. Craw. He was the first "City Engineer," the "City" being incorporated March 5, 1836, bounded east by the lot line in the centre of Perry street. Prior to this the east and south bounds of the 2-acre lots had been those of the village. The 10-acre lots were annexed in 1850. Mr. Shier was ordered by the Council August 3, 1836, to establish the lines of streets in the city, and report his doings to Council for record, but I do not find that he ever made any such report, though I searched for it in the City Clerk's Records. May 30, 1838, he was ordered to proceed in setting stones for corners of streets. Mr. Shier came to this country from Scotland, where, I am told, he had received a very thorough training as an engineer. He subsequently located in Canada. Mr. John Whitelaw, our Water Works Engineer, informs me that he took his first lessons in surveying over there from Mr. Shier, who was a very careful, painstaking surveyor. The stones he set here were substantial ones, with hole in top, set in the centres of streets. The stones previously set by Ahaz Merchant, and others, had generally been on the street corners, the outside faces of the stones being on the street lines. Some of these still exist. April 21, 1841, the Council, on resolution of Mr. Bolton, ordered the City Clerk to record in the City records an exact copy of Seth Pease's map and notes of the "city," and also record his map of the Western Reserve in the county's records, but this was not done. It remained for Pillsbury, who was elected City Civil Engineer April, 1853, to record the original surveys of our city, and the work remains a credit to his memory. He makes a statement in an old volume in the Engineer's office, that when he took office he found not one solitary book, map, plan or record of any description in the engineer's office, and therefore he started this record as "No. 1 and Vol. 1 of Engineer's Records." The reason he found nothing undoubtedly was that before his time the City work was done by private engineers, who kept the notes of their work as their own property—as I find that May 3, 1854, the Board of Improvements made a report to Council, which was accepted, in favor of a general survey of the city, of employing three young men regularly in the engineer's office, *and of making the furniture, books, maps, &c.,*

in the office the property of the city, showing that previously they had not been.

I will speak but briefly of that part of our city west of the river. It lies in the Township of Brooklyn. That part of the Land Company's Tract west of the Cuyahoga was surveyed in 1806 by Abraham Tappan, of Painesville, in continuation of the plan east of the Cuyahoga. A large portion of the Township of Brooklyn was incorporated as the "City of Ohio" in 1836, and annexed to Cleveland in 1854. Nearly all of this City of Ohio is embraced in the following large and important subdivisions—namely, "The Buffalo Company's," "Barber and Lord's," "Willeyville," "Taylor Farm," "S. S. Stone's" and "Benedict and Root's," the first being made in 1833, and the others subsequently. Ahaz Merchant was the surveyor of all these allotments. They are all on record at the Court House, and so I need not refer to them. Some of the streets laid out by these allotments are defined by monuments, but there is still a great dearth of "stone monuments" over there (except in the cemetery).

Having now concluded what I have to say on the old surveys, I may, perhaps, be permitted—though foreign to the subject of this paper—to say a few words in conclusion regarding the present regulations of the city in passing upon allotment plats and street dedications. Prior to 1875 there was nothing in the laws of this State to prevent owners of land putting on record allotments laying out lots and streets in any manner they saw fit. They necessarily took advantage of this lack of restraint, and each man allotted his land and laid his streets to suit himself. This accounts for the many narrow, crooked and unconnecting streets in the portion of our city outside the original portion. In 1875 the Legislature passed a law requiring the approval of plats by the City Council before they could be recorded, and to govern the Board of Improvements in recommending the approval of plats, an ordinance was prepared under the direction of the City Engineer, B. F. Morse, and passed by the Council June 26, 1882. This prescribes that streets laid out in new plats shall as nearly as practicable be in continuation of streets already laid out, shall be properly defined by stone monuments, shall be properly graded, ditched, bridged or culverted as required, and the title shall be good in the dedicator; streams and ravines must be indicated on the plat, and the lots must be properly numbered and figured, so that they can be located from the monuments. All these requirements are sound. I cannot say that they have all been strictly lived up to by the Board and Council since the ordinance was passed, but they have been very largely, and especially as to the proper defining and title of streets; and while we cannot help what was done before the law of 1875 was passed, we can guard against similar action in the future, and certainly all of our surveyors are, or should be, as much interested in seeing that the ordinance is complied with as are the city authorities or the public generally.

RAINFALL.

DOES THE WIND CAUSE THE DIMINISHED AMOUNT OF RAIN COLLECTED IN ELEVATED RAIN GAUGES.

BY DESMOND FITZGERALD, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read May 21, 1884.]

While making some experiments a few years since, the writer ascertained that there was a considerable difference in the amount of rain that could be collected in a rain gauge according to the height at which it was placed above the surface of the ground.

Subsequent investigations showed that philosophers had been puzzling over this matter for more than a century. Volumes have been written on the subject, and while some have dismissed the observations summarily as impossible, others have brought into the field some of the most ingenious theories both mathematical and philosophical to explain the phenomenon.

Much information and discussion on the whole subject of rainfall may be found in the reports of the British Association for the Advancement of Science. It will be sufficient to refer here briefly to what has been done in the way of experiment or analysis.

Many years ago Professor Phillips placed three gauges, one on the ground, in the garden of the York Museum, one on its roof, 43 feet 8 inches above the first, and a third on a pole nine feet above the battlements of the great tower of York minster, 212 feet 10 inches above the ground. The ratios of three years' observations, from 1832–35, were as follows: Calling the ground gauge 100, the roof gauge gave 79.7 per cent and the highest gauge 59.6 per cent, showing a rate of decrease not very far from 3 $\sqrt{h}$.

M. Arago found during twelve years' observations on the terrace of the observatory at Paris the annual fall of rain was 19.88, and 71 feet lower 22.21. The experiments made at Castle House Calne, Wilts, are generally referred to as being the most complete. Ten rain gauges were observed, the first placed level with the turf and the others at the heights of 2 inches, 6 inches, 1 foot, 2 feet, 3 feet, 5 feet, 10 feet and 20 feet, respectively, above No. 1. Afterwards a pit gauge was added. The diameter of the gauges was 8 inches. The mean ratios for four years and five months to the 1 foot gauge and to the pit gauge were as follows :

ONE FOOT GAUGE.		PIT GAUGE 1.000.	
Level	1 065	Level	1.025
2 inches	1.048	2 inches	.999
6 inches	1.014	6 inches	.969
1 foot	1.000	1 foot	.954
2 feet	.989	2 feet	.947
3 feet	.983	3 feet	.940
5 feet	.965	5 feet	.923
10 feet	.950	10 feet	.909
20 feet	.941	20 feet	.901

These experiments were intended to produce a rule for calculating the proper record of a gauge knowing its height above the ground, limited of course to a range of 20 feet ; for instance, to get the ground fall if a gauge, say 6 inches above the ground, with a record of 46.31, 46.31 ÷ .969

= 47.79 ground fall, or if the gauge is 6 feet 6 inches above the ground and its record be 44.48, 44.48 ÷ .920 = 48.34 true ground fall. One of the most remarkable results to quote from the report of the committee, was the rapid increase in amount of rain collected within 1 foot of the ground and the slight alteration from 7 to 20 feet. In general the 1 foot gauge gave 5 per cent. less than the pit gauge. By far the most scientific analysis of this subject was made by Prof. W. S. Jevons, of University College, in the *Philosophical Magazine* for 1861, p. 421. The whole aim of the article is to show the fallacy of ascribing the smaller amounts collected in elevated gauges to the diminished rainfall of higher stratas, and to explain the phenonemon by the action of the wind. He gives credit to an intelligent observer, Mr. H. Bcace, of Penzance, for having first called attention to the matter after four months' experiment. Mr. Boace says: "Having observed that the difference between the first and the other gauges varied with more or less wind, its velocity has been registered from observations, but not having an accurate anemometer we cannot yet offer any certain conclusion further than this, that the difference of the quantity of rain received in a gauge placed on the top of a building and one at a level with the surface of the ground is, for some reason or other, proportional to the velocity of the wind." Prof. Jevons goes on to say: "Again, taking the measurements of rain made by Luke Howard, and arranging them in the order of the ratio of the quantities in the lower and higher gauges, we find that we have also arranged them almost exactly in the order of the amount of accompanying wind." These experiments of Mr. Howard were not very extensive, and, in the case of the wind, were not the result of instrumental observation. The writer is inclined to give more weight to the comparison of three gauges kept at the Greenwich Observatory for twenty years, which, according to Prof. Jevons, show no ratio to the velocity of the wind, while, according to the same authority, "Both Arago and Prof. Phillips have recorded unequivocally that a deficiency of rain in the upper gauges occurs, even during a perfect calm." In our own country, Prof. Francis E. Nipher, of St. Louis, has experimented and written on the subject.

A very interesting article from his pen will be found in the volume for 1878 of the publications of the American Association for the Advancement of Science. He says, after calling attention to the fact that Dr. Traill and others have suggested the wind theory, "Jevons proved that condensation in the lower strata is in all possible cases inappreciable, and pointed out with clearness the actions of the wind in robbing the elevated gauges of their rain." Professor Nipher experimented with sixteen gauges on the roof of an observatory, and came to the conclusion that the amounts collected depended upon the direction and force of the wind. Professor Nipher devised a shield for protecting an elevated gauge from the action of the wind, and found "that when the shield is placed at an elevation of 3¼ inches [above the rim of the gauge], the pole gauge gives the same indications as the common gauge at the ground, although differing in level 112 feet." Professor Nipher's conclusions are as follows:

"It appears therefore—

"1. That the so called correction due to the altitude of a rain gauge may be reduced to *nil* by properly shielding the gauge from the wind.

"2. That the gauge may then have any convenient altitude when not upon a roof. On the roof of a building it is probable that if the shielded gauge be properly elevated, the true ground rainfall will also be obtained. This point will receive further attention." *

So much for what has been done by others in this direction. The writer will now proceed to give the results of his own experiments during the past five years. Two gauges have been kept for comparison, one at a height of 2 feet 6 inches above the ground. excellently located in the centre of a very large yard, free from obstacles, and the second at a distance of 150 feet from the first, and at an elevation of 20 feet 4 inches above the lower gauge. Both gauges are of 14.85 inches diameter. One hundred ounces in a gauge of this size gives an inch of rain. A careful examination of the comparative areas of the two gauges was made at the end of the experiments with the result of a difference of less than half of one p. c., the upper gauge being the larger of the two by this amount. Both gauges were turned to a sharp edge. The gauges were placed at Chestnut Hill Reservoir in the City of Boston, and the observations for the velocity of the wind were taken from the signal service observations in another part of the city five miles distant.

The following table shows the observation of each storm in the two gauges with the ratio in the third column of the higher to the lower gauge. In the next column is the ratio or per cent of difference between the two gauges, which, if the wind theory is correct, should vary with the velocity of the wind. Two profiles are submitted, the upper showing the ratio of difference between the two gauges for each storm admitted for comparison, and the lower showing the velocity of the wind at the same time in miles per hour. All storms of less than .2 of an inch have been excluded from the comparison for the reason that an undue weight in ratio might be given to a trifling error of observation. For instance, the difference between .01 inches and .02 inches would be 50 per cent., which might arise easily from error of observation.

It will be noticed that the profiles do not show any harmony of variation. Two other profiles have been compared, the first showing the ratios for all the storms of the same velocity, and the second the relative values of the several observations. For instance, of the storms admitted there were, during the five years, thirteen storms at eight miles an hour, The average per cent. of difference between the two gauges (referred to the ground gauge) for this group of rains was 4.5, which is plotted in its appropriate place. A comparison of this profile with a curve of velocities, shows no distinct law of agreement. If, however, the values of the observations are studied, as shown in the lower profile of diagram 2, a faint suspicion of a tendency to rise with velocities may be noticed. At any rate, on the strength of it, the writer has prepared a series of experiments with nine gauges and a self-recording anemometer, from which in the course of time some more definite result may be reached.

Snow falls and mixtures of snow and rain are not included in the table of data. It will be seen. that with only five exceptions, during the period 1879–84, the upper gauge delivered materially less water than the ground gauge, the average difference being 10.6 per cent. for the whole period.

*Professor Nipher has not been able to prosecute his researches further in this direction.

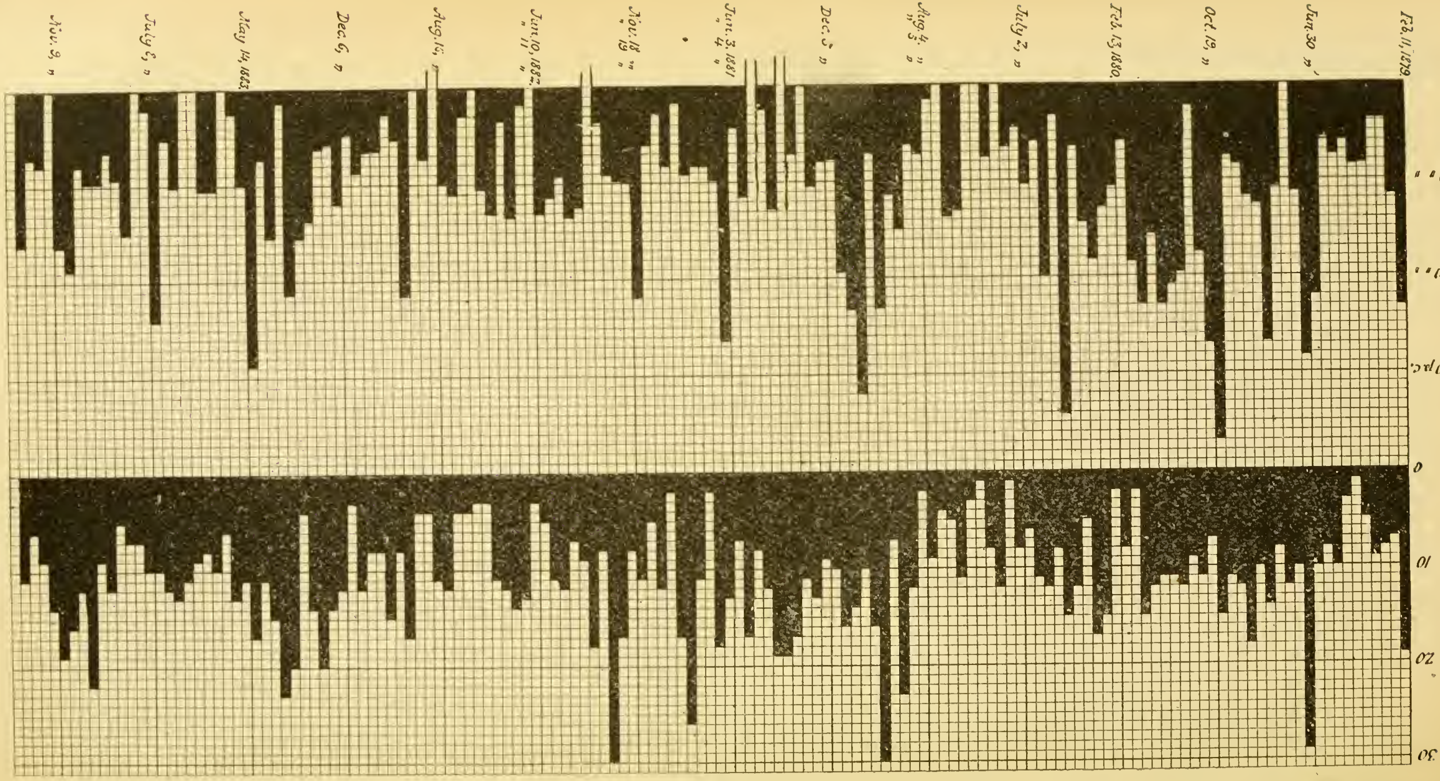


DIAGRAM No. 1.

Profiles Comparing Velocities of the Wind and Ratios of Differences between Amounts of Rain Collected in Ground and Elevated Gauges.—D. Fitzgerald, 1884.

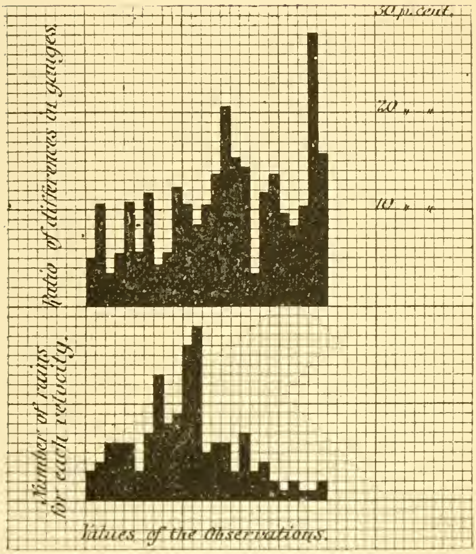


DIAGRAM No. 2.

(Rains Grouped According to Velocities of the Wind.

TABLE OF RAINFALL COLLECTED IN GROUND AND ELEVATED GAUGES, 1879-84—BY DESMOND FITZGERALD.

Date.	Duration.	Ground gauge.	Elevated gauge.	Ratio of elevated gauge to ground gauge.	Ratio of difference to ground gauge.	Direction of wind.	Velocity of wind, miles per hour.	Remarks.
1879.								
Feb. 11 " 12	6:00 p. m. to 10:45 a. m.	1.30	1.00	76.9	23.1	SW	19	The elevated gauge is 25 ft. above the ground, and 20 ft. 4 in. above the ground gauge. The latter is 2 ft. 6 in. above the ground, which slopes 2 ft. 2 in. in the 150 ft. distance which divides them.
Mar. 30	5:00 to 8:45 a. m.	.26	.23	88.4	11.6	W	7	
Apr. 15 " 16	3:30 p. m. to 3:00 a. m.	.27	.26	96.3	3.7	E	8	
" 29	12:15 to 9:00 a. m.	.54	.52	96.3	3.7	E	9	
" 29 " 30	4:15 p. m. to 10:00 a. m.	1.09	1.00	91.7	8.3	SE	5	
" 30	9:55 to 11:15 p m.	.36	.33	91.6	8.4	W	1	
May 16	1:00 a. m. to 5:15 p. m.	.13	.09	69.2	30.8	E	5	
" 19	7:30 a. m. to 2:30 p. m.	.68	.64	94.1	5.9	SE	3	
" 19	8:00 to 8:30 p. m.	.04	.02	50.0	50.0	E	2	
June 2 " 3 " 4	5:10 p. m. to 3:00 p. m.	1.38	1.28	92.7	7.3	NW E S	10	
" 5	4:40 to 5:05 p. m.	09	.08	88.9	11.1	NW	12	
" 6	5:10 to 5:45 p. m.	.18	.17	94.4	5.6	NW	29	
" 10	2:50 to 3:15 a. m.	.05	.05	100.0	0.0	S	4	
" 10 " 11	7:45 p. m. to 5:00 a. m.	.07	.08	114.3	14.3	N	7	
" 13	1:00 to 3:00 a. m.	.07	.06	85.7	14.3	W	4	
" 15 " 16	6:00 a. m. to 2:00 p. m.	.71	.67	94.3	5.7	NW N	8	Showers.
" 26	11:40 a. m. to noon	.17	.17	100.0	0.0	SW	18	
" 28	3:55 to 4:05 p. m.	.14	.13	92.8	7.2	SW	12	
" 28 " 29	6:45 p. m. to 1:30 a. m.	.11	.11	100.0	0.0	SW	11	
" 29	2:30 to 6:00 p. m.	1.41	1.10	78.0	22.0	SE	10	
" 30	1:35 to 1:55 p. m.	.39	.28	71.8	28.2	NW	29	3:20 to 4 p. m., 85 in. in 40 min. Thunder storm.
July 4	4:15 to 5:00 p. m.	.12	.10	83.3	16.7	SE	8	
" 7 " 8	12:30 p. m. to 11:00 a. m.	.72	.64	88.8	11.2	SW	10	
" 22	1:45 to 2:05 a. m.	.23	.23	100.0	0.0	SW	12	
" 22	11:10 to 11:35 p. m.	.12	.12	100.0	0.0	SW	9	
" 26 " 27	1:45 p. m. to 5:00 a. m.	1.02	.91	89.2	10.8	N	8	
Aug. 16 " 17 " 18 " 19	7:35 a. m. to 6:30 a. m.	6.23	4.56	73.2	26.8	NE	14*	* From 2:55 p. m., Aug. 18th, to 1:00 a. m. 19th, 10 hours, 3.40 in. fell. During most rapid parts .35 in. in 13 min.
" 24	3:45 to 4:05 p. m.	.40	.35	87.5	12.5	SW	10†	† About the same as above.
" 29	10:05 to 11:05 p. m.	.10	.10	100.0	0.0	SE	2	
Sept. 4	1:30 to 6:45 a. m.	.68	.60	88.2	11.8	E	18	
" 8	3:20 to 11:30 a. m.	.48	.44	91.6	8.4	S	12	
" 14	3:00 to 6:15 p. m.	.27	.25	92 6	7.4	S	11	
" 24	2:25 to 6:30 p. m.	.38	.24	63.1	36.9	SW	15	
Oct. 19	3:15 to 8:45 a. m.	.26	.19	73.0	27 0	W	7	
" 28	10:50 a. m. to 8:00 p. m.	.40	.33	82.5	17.5	S	11	
Nov. 12 " 13	5:00 p. m. to 3:45 a. m.	.46	.45	97.8	2.2	W N	9	
" 29	1:30 a. m to 3:00 p. m.	.51	.41	80.4	19.6	SW	12	
Dec. 4	1:30 to 7:30 a. m.	.15	.14	93.3	6.7	W	8	
" 6 " 7	1:00 p. m. to 7:30 a. m.	.48	.38	79.1	20.9	E SW	11	
" 8	11:30 a. m. to 3:45 p. m.	.11	.11	100.0	0.0	SW	7	
" 10 " 11	8:30 p. m. to 8:30 a. m.	.13	.10	76.9	23.1	S	14	
" 24	5:15 a. m. to 2:00 p. m.	.57	.44	77.2	22.8	E to NW	11	
" 29	6:00 to 9:30 a. m.	.10	.08	80.0	20.0	Calm	0	
1880.								
Jan. 6	1:30 to 10:15 p. m.	.45	.38	84.4	15.6	SE to NW	12	
" 22 " 23	7:15 p. m. to 7:00 a. m.	.35	.27	77.1	22.9	SE S	15	
" 27 " 28	11:15 a. m. to 6:30 a. m.	.49	.40	81.6	18.4	NE W	2	
Feb. 12 " 13	6:00 a. m. to 2:00 p. m.	.68	.64	94.1	5.9	SW	8	
" 13 " 14	6:30 p. m. to 3:00 a. m.	.84	.75	89.3	10.7	SE	2	

TABLE OF RAINFALL COLLECTED IN GROUND AND ELEVATED GAUGES, 1879-84—BY DESMOND FITZGERALD.

Date.	Duration.	Ground gauge.	Elevated gauge.	Ratio of elevated gauge to ground gauge.	Ratio of difference to ground gauge.	Direction of wind.	Velocity of wind, miles per hour.	Remarks.
1880.								
Feb. 18	7:30 to 11:45 p. m.	.12	.09	75.0	25.0	SW	20	
" 26	5:30 to 11:15 p. m.	.08	.08	100.0	0.	NW	2	
" 28	9:30 p. m. to	.62	.54	87.1	12.9	SW	15	
" 29	9:00 a. m.							
Mar. 3	8:15 p. m. to	.22	.18	81.8	18.2	SW	17	
" 4	2:00 a. m.							
" 5	5:50 to 10:30 a. m.	.35	.30	85.7	14.3	SE	5	
Apr. 16	8:30 a. m. to	.77	.72	93.5	6.5	N	12	
" 17	2:15 a. m.					SE		
" 30	12:30 to 7:15 a. m.	.79	.52	65.8	34.2	S	15	
May 2	8:00 a. m. to 2:15 p.m.	.62	.60	96.8	3.2	SW	8	
" 28	2:40 to 3:45 p. m.	.25	.20	80.0	20.0	NW	12	
" 30	11:30 a. m. to	.34	.32	94.1	5.9	SE	11	
" 31	11:00 a. m.							
June 2	12:10 to 8:45 a. m.	.29	.26	89.6	10.4	N	6	
" 12	5:00 to 5:45 p. m.	.18	.17	94.4	5.6	W	10	
" 26	1:45 to 2:00 p. m.	.11	.10	90.9	9.1	W	16	
" 28	3:45 to 4:00 p. m.	.05	.04	80.0	20.0	S	12	
July 2	1:25 a. m. to 2:30 p. m.	.66	.63	95.4	4.6	E	8	
" 3	5:45 a. m. to 2:30 p. m.	.31	.29	93.5	6.5	E	1	
" 9	8:15 to 9:45 a. m.	.28	.28	100.0	0.	W	12	
" 12	9:00 p. m. to	1.33	1.23	92.5	7.5	S	8	
" 13	9:30 a. m.							
" 15	10:00 a. m. to 4:30 p.m.	.36	.36	100.0	0.	S	1	
" 16	10:15 a. m. to 1:30 p. m.	.23	.23	100.0	0.	E	3	
" 20	1:00 p. m. to	1.99	1.73	86.9	13.1	SE	11	From 1:33 p.m. to 2:13 p. m. 40 mts. 1.28″ fell.
" 21	4:00 a. m.					W		
" 22	6:00 p. m. to	.58	.50	86.2	13.8	NE	5	
" 23	5:30 a. m.					NW		
" 27	7:00 to 10:45 p. m.	.24	.24	100.0	0.	NW	4	
Aug. 3	4:00 p. m. to	.62	.61	98.4	1.6	N	9	
" 4	12:30 p. m.					NW		
" 4	2:20 p. m. to	.56	.52	92.8	7.2	NW	2	
" 5	7:00 a. m.					Calm.		
" 29	1:30 p. m. to	1.29	1.21	93.8	6.2	NE	12	
" 30	10:00 a. m.							
Sept. 9	5:00 p. m. to	1.00	.85	85.0	15.0	NE	23	
" 10	3:00 p. m.							
" 13	10:00 p. m. to	.71	.63	88.7	11.3	NW	7	
" 14	3:00 p. m.							
Oct. 22	1:15 p. m. to	1.69	1.30	76.9	23.1	E	30	
" 23	3:00 a. m.					W		
" 30	7:00 p. m. to	.71	.66	92.9	7.1	SE	16	
" 31	7:30 a. m.					S—W		
Nov. 5	12:30 p. m. to	.25	.17	68.0	32.0	SE	10	
" 6	2:00 a. m.							
" 6	7:30 p. m. to	.43	.33	76.7	23.3	SE	14	
" 7	5:00 a. m.					SW		
" 11	9:15 a. m. to 6:00 p.m.	.41	.33	80.5	19.5	SE	16	
" 20	12:45 to 8:00 p. m.	1.04	.96	92.3	7.7	SE to W	10	
Dec. 5	9:30 a. m. to 5:30 p.m.	.51	.47	92.1	7.9	SW to SE	9	
" 14	10:30 p. m. to	.38	.34	89.5	10.5	SE	13	
" 15	5:00 a. m.							
1881.								
Jan. 9	Snow, 8:40 p. m. to 2:00	2.20	2.20	100.	0.	SE to NW	11	The snow was only about .05 in the storm, and so good a record of the whole was obtained that it is admitted.
" 10	am. then rain to 3:30 p.m							
Feb. 12	10:50 a. m. to 9:30 p.m	1.55	1.44	92.9	7.1	E	17	
Mar. 3	8:00 p. m. to	.92	.96	104.3	—4.3	E	19	
" 4	8:30 p. m.							
" 9	1:00 p. m.	2.43	2.12	87.2	12.8	NE	19	
" 10	to					N		
" 11	3:00 a. m.					NW		
May 6	5:15 a. m. to 4:00 p. m	.40	.39	97.5	2.5	SE	12	
" 15	4:30 a. m. to 10:30 a.m.	.25	.30	120.0	20.0	SE	8	
" 16	12:30 p. m.	1.49	1.32	88.6	11.4	NE	17	
" 17								
" 18	to							
" 19	5:30 p. m.							
" 30	7:40 to 10:30 p. m.	.46	.44	95.6	4.4	SW	7	

TABLE OF RAINFALL COLLECTED IN GROUND AND ELEVATED GAUGES, 1879-84—BY DESMOND FITZGERALD.

Date.	Duration.	Ground gauge.	Elevated gauge.	Ratio of elevated gauge to ground gauge.	Ratio of difference to ground gauge	Direction of wind.	Velocity of wind, miles per hour.	Remarks.
1881.								
June 3	8:30 p. m. to	.87	.64	73.6	26.4	NE	13	
" 4	12 noon.					NW		
" 10	1:15 a. m. to	3.83	3.50	90.1	9.9	NE	18	
" 11	1:00 p. m.							
" 27	9:30 p. m. to	.48	.44	91.7	8.3	SE	2	
" 28	5:00 a. m.					SW		
" 28	9:15 to 11:30 p. m.	.18	.17	94.4	5.6	S	7	
" 30	5:30 to 6:15 p. m.	.24	.22	91.7	8.3	NW	11	
July 1	2:45 to 5:00 a. m.	.17	.14	82.4	17.6	NW	3	
" 1	3:15 to 5:00 p. m.	.33	.30	90.9	9.1	NW	26	Thunder storm
" 4	3:00 to 5:00 p. m.	.07	.07	100.0	0.0	E	3	
" 8	6:00 to 10:15 a m.	.15	.15	100.0	0.0	S	1	
" 21	1:40 to 2:00 p. m.	.48	.36	75.0	25.0			Large hail-stones, .28 in. in 4 min. Only record of wind in p. m. at 3.23.
" 26	3:00 to 6:00 a. m.	.61	.60	98.3	1.7	SE	17	
" 26	9:15 to 10:00 a. m.	.49	.45	91.8	8.2	NW	2	
Sept. 2	12:30 p. m. to	1.79	1.74	97.2	2.8	NE	*12	
" 3	9:15 a m.							
Oct. 29	12:30 p. m.					E		
" 30		1.65	1.55	93.9	6.1	S	5	*During part of this rain .78 in. fell in 34 min.
" 31	to							
Nov. 1	1:30 p. m.					W		
" 3	11:00 a. m. to	.64	.50	78.1	21 9	S	11	
" 4	11:45 a. m.							
" 18	10:30 p. m. to	1.78	1.60	89.9	10.1	W	8	
" 19	9:45 p. m.					E		
1882.								
Mch. 6	2:30 to 9:15 p. m.	.11	.10	90.9	9.1	W	9	
Apr. 19	4:45 p. m. to	.82	.74	90.2	9.8	W	17	
" 20	2:30 a. m.							
" 27	5:30 a. m. to	1.41	1.28	90.9	9.1	NE	30	A very little snow.
" 28	3:00 a. m							
May 9	1:00 to 5:45 a. m.	.56	.54	96.4	3.6	W	8	
" 11	8:30 a. m. to 1:00 p.m.	.11	.10	90.9	9.1	NE	24	
" 12	7:10 a. m to							
" 13		2.24	2.58	110.7	10.7	NE	18	
" 14								
" 15	1:30 p. m.							
" 18	Showers.	.10	.10	100.0	0.0	E	19	Showers.
" 19								
" 20	6:30 a. m. to 5:30 p. m.	.48	.42	87.5	12.5	NW	9	
" 20	7:15 p. m. to	.59	.51	86.4	13 6	W	7	
" 21	10:00 a. m.							
" 23	5:40 a. m. to 2:15 p. m.	.54	.49	90.7	9.3	E	12	
" 25	12:15 to 6:30 p. m.	.15	.13	86.7	13.3	Calm.	0	
" 29	12:30 to 8:45 a. m.	.53	.47	88.7	11.3	NW	11	
June 4	7:30 a. m. to 3:00 p. m.	.23	.20	86.9	13.1	SE to NE	5	
" 10	11:00 p. m. to	.28	.28	100.0	0.0	N	3	
" 11	9:00 a. m.							
" 18	9:00 a. m. to	.57	.56	98.2	1.8	NE	13	
" 19	2:00 a. m.							
" 30	6:30 p. m.							
July 1	to	.59	.51	86.4	13.6	W	14	
" 2	9:00 a. m.							
" 4	8:00 p. m.							
" 5	to	.59	.57	96.6	3.4	NE	12	
" 6	2:30 a. m.							
" 13	6:00 to 8:20 a. m.	.23	.20	86.9	13.1	S	11	
" 19	1:15 to 2:20 p. m.	.48	.43	89.6	10.4	S	3	
" 19	4:45 to 5:00 p. m.	32	.32	100.0	0.0	S	3	
" 28	8:55 to 10:00 a. m.	.35	.34	97.1	2.9	SE	4	
" 28	4:10 to 6:00 p. m.	.36	.32	88.9	11.1	E	4	
Aug. 8	9:30 p. m. to	.40	.36	90.0	10.0	SW	12	
" 9	12:30 a. m.							
" 16	11.15 a. m. to 4:00 p. m.	.43	.45	104.6	4.6	E	11	
" 24	4:15 to 11:30 a. m.	.41	.38	92.7	7.3	S	4	
Sept. 8	7:30 p. m. to	.33	.33	100.0	0.0	NW	4	
" 9	11:00 a. m.							
" 11	10:30 a. m. to	3.00	2.35	78.3	21.7	NE	17	
" 12	10:45 a. m.							

TABLE OF RAINFALL COLLECTED IN GROUND AND ELEVATED GAUGES, 1879–84—BY DESMOND FITZGERALD.

DATE.	DURATION.	Ground gauge.	Elevated gauge.	Ratio of elevated gauge to ground gauge.	Ratio of difference to ground gauge.	Direction of wind.	Velocity of wind, miles per hour.	REMARKS.
1882.								
Sept. 14	Showers in a. m.	.03	0.3	100.0	0.0	SE	12	
" 14	9:05 to 10:30 p. m.	1.13	1.07	94.7	5.3	SW	8	Exactly one in. fell in 45 min.
" 20	11:40 to 11:55 a. m.	.05	.05	100.0	0 0	SW	4	
" 21	4:55 a. m. to 5:30 p. m.	1.13	1.10	97.3	2.7	NE	15	
" 22	Showers.	.14	.14	100.0	0.0	NE	7	
" 22	7:30 p. m. to	2.55	2.38	93.3	6.7	S	8	
" 23	8:15 a. m.							
" 24	5:15 to 9:15 a. m.	.44	.41	93.2	6.8	W	8	
" 29	2:00 to 8:00 p. m.	.35	.20	57.1	42.9	NE	15	
Oct. 14	6:00 a. m. to 2:45 p. m.	1.25	1.14	91.2	8.8	E to NW	12	
" 18	10:00 p. m. to	.42	.40	95.2	4.8	NW	3	
" 19	7:30 p. m,							
Dec. 6	12:15 to 4:30 a. m.	.25	.22	88.0	12.0	S	12	
" 22	5:45 p. m. to	.69	.65	94.2	5.8	NE	14	
" 23	11:30 a. m.							
1883.								
Jan. 13	7:30 p. m. to	.32	.30	93.8	6.2	SW	20	
" 14	8:00 a. m.							
" 20	7:15 p. m. to	.80	.69	86.3	13.7	W	14	
" 21	3:45 a. m.							
" 28	5:30 a. m. to	.26	.22	84.6	15.4	NE	4	
" 29	4:00 a. m.							
" 31	12:05 to 4:00 p. m.	.47	.37	78.7	21.3	SE	20	
Mar. 10	12:30 to 9:30 p. m.	.75	.74	98.7	1.3	NE	23	
" 20	3:50 to 7:00 a. m.	.65	.55	84.6	15.4	SW	15	
Apr. 12	7:45 p. m. to	1.11	1.03	92.8	7.2	NE	11	
" 13	5:00 a. m.							
" 20	9.15 a. m. to 4.00 p. m.	.38	.27	71.1	28.9	NW	17	
May 11	1:00 to 5:15 p. m.	.16	.14	87.5	12.5	SE	7	
" 14	9:00 p. m. to	.80	.72	90.0	10.0	NE	11	
" 15	8:00 a. m.							
" 22	6:30 a. m. to	2.28	2.22	97.4	2 6	NE	13	
" 23	1:30 a. m.							
" 23	12:05 to 1:30 p. m.	.06	.05	83.3	16.7	NE	13	
" 23	7:00 p. m. to	.24	.24	100.0	0.0	SW	6	
" 24	5:00 a. m.							
" 31	4:15 to 4:55 p. m.	.47	.42	89.3	10.7	SW	10	
June 6	12:55 to 2:00 p.m.	.47	.42	89.3	10.7	SW	8	
" 6	6:00 to 11:55 p. m.	.10	.09	90.0	10.0	W	6	
" 7	7:00 to 11:55 p. m.	.21	.21	100.0	0.0	SW	9	
" 11	6:00 to 7:00 a. m.	.04	.04	100.0	0.0	S	8	
" 11	5:00 to 5:35 p. m.	.25	.25	100.0	0.0	S	11	
" 27	3:00 p. m. to	.49	.44	89.8	10.2	E	13	
" 28	8:45 a. m.							
" 29	4:30 to 5:05 p. m.	.59	.56	94 9	5.1	SW	12	
July 2	6:00 to 8:30 p. m.	.29	.22	75.9	24.1	SW	10	
" 4	8:00 to 11:10 p. m.	.08	.10	125.0	25.0	SW	8	
" 8	11:30 a. m. to 11:45 p. m.	.51	.50	98.0	2.0	E	10	
" 13	3:30 to 4:30 a. m.	.25	.25	100.0	0.0	SW	7	
" 28	3:30 to 6:15 a. m.	.20	.17	85.0	15.0	S	7	
" 28	10:30 a. m. to	.75	.68	90.7	9.3	SW	5	
" 29	3:30 a. m.							Very little rain fell from July 29th to Sept. 24th, viz.: .48 in.
Sep. 24	4:00 p. m. to	.77	.72	93.5	6.5	S	12	
" 25	12:45 a. m.							
" 30	9:45 a. m. to 10:00 p. m.	.31	.28	90.3	9.7	E	9	
Oct. 2	9:45 a. m. to 4:00 p. m.	1.24	1.12	90.3	9.7	SE	22	
" 13	7:30 p. m. to	.89	.82	92.1	7.9	SW	12	
" 14	4:15 p. m.							
" 23	9:30 p. m. to	1.65	1.34	81.2	18.8	NE	16	
" 24	11:15 p. m.							
" 26	12:45 to 4:50 p. m.	.15	.15	100.0	0.0	NE	3	
" 29	3:50 a. m. to	1.11	.93	83.8	16.2	S	19	
" 30	5:30 a. m.							
Nov. 9	1:50 to 4:10 p. m.	.21	.21	100.0	0.0	S	14	
" 26	5:30 p. m. to	1.51	1.39	92.0	8.0	E	9	
" 27	2:45 a. m.							
1884.								
Jan. 24	9:30 to 11:30 p. m.	.84	.78	92.9	7.1	NW	6	
Feb. 17	2:45 p. m. to	.74	.62	83.8	16.2	NE	11	
" 18	11:00 p. m.							

TABLE OF RAINS GROUPED ACCORDING TO VELOCITY OF THE WIND.

Velocity of the wind. Miles per hour.	Number of rains admitted.	Percentage of difference in gauges.	Velocity of the wind. Miles per hour.	Number of rains admitted.	Percentage of difference in gauges.
1	3	5	14	6	13.8
2	4	10.5	15	6	20.8
3	6	3.2	16	3	15.1
4	6	5.7	17	7	14.3
5	6	10.8	18	3	3.2
6	3	5.8	19	4	11.9
7	7	11.8	20	2	13.7
8	13	4.5	22	1	9.7
9	8	5.7	23	2	8.1
10	9	12.2	26	1	9.1
11	16	10.5	29	1	28.2
12	18	8.3	30	2	15.8
13	5	10.5			

HENRY BESSEMER AND HIS INVENTIONS.

A SHORT ACCOUNT OF THE BESSEMER PROCESS AND OF THE FIRST "BLOW" AT THE STEEL WORKS OF THE CLEVELAND ROLLING MILL CO., CLEVELAND, O.

BY J. F. HOLLOWAY, PRESIDENT OF CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read May 13, 1884.]

When the Civil Engineers' Club accepted the invitation of the Cleveland Rolling Mill Co. to visit their steel works in the Eighteenth Ward, it was suggested that a short paper upon the discovery of the Bessemer process, with some account of the inventor, would add to the interest of the occasion. I was in hopes to obtain from some of our members who are engaged in the manufacture of steel a paper that would treat of the subject in a thoroughly scientific manner; and I have no doubt but that I could have done so, but for the reason that I was called out of the city on business, and did not have an opportunity of conferring with any of them upon the subject. This is why I appear before you instead of those of our members who, by study, practice and experience, are so much better qualified to speak on this very interesting topic.

As there will join us on this excursion those, not members of the Club, who have never witnessed the conversion of cast iron into steel, by this method, I have thought that some reference to the early history of the invention, and as to how it came about, would be of interest.

The production and use of iron date back to a time coincident nearly with the beginning of our history as a race. Its mode of manufacture, traced as it has been far into the ages that are past, had still a history which had been lost long before ours was first begun. How crude the appliances that were used in producing it at first, and the changes that from time to time have taken place in its mode of manufacture, are well known to all; and the fact that for so many thousand years iron was made, and converted into steel, by processes that changed so little, serves to give greater prominence to another fact, which is, that in our day, and within the thirty years just past, there came into the ranks of

these iron and steel makers, one, who not himself either one or the other, has invented and perfected a method of making both iron and steel, which has revolutionized the whole world, and which has advanced the art more in the lifetime of one generation than all that had been done since the days of "Tubal Cain." This, I am aware, is a broad assertion; but when you remember that the invention of Henry Bessemer has made it possible to convert, as you will see, 10 tons of crude pig iron into steel of almost any degree of tenacity or hardness, within the short space of 12 or 13 minutes, you will have some idea of the advancement made in the art, as compared with the olden time when a group of Egyptians, Hebrews or Hindoos, with their bamboo reeds and pig-skin bellows, labored long and hard to produce iron or steel enough to make a single knife blade, or the simplest piece of ironmongery. The Bessemer steel works (all of which have been built within a few years) have a combined capacity which has yielded enough steel to cover all civilized lands with a network of railroads, has laid numerous cables under almost every known sea, has filled the air with lines over which lightning, harnessed to thought, has made distant lands our neighbors, and over which, in times of disaster and calamities, there has often come that one touch of kindness which, as Shakespeare so well says, "makes all the world akin."

Henry Bessemer was born at Charlton, in Hertfordshire, England, in 1813. While still a young man he showed a decided genius for mechanical pursuits, and his father wisely purchased for him a beautiful Holtzafbel foot lathe, on which he early began what has since become a splendid career.

At the age of 18 he left home for London, knowing, as he has since said, "no one;" he, however, on his arrival there, began work as an engraver and modeler, and soon found plenty to do. But he had a genius for inventing as well, and hearing in some way of the enormous frauds practiced upon the Government by the use of counterfeited and canceled stamps, he began a study of the subject, and after a long time produced what he thought was a very much better system. In connection with this, his first, and at that time his most important invention, there are some interesting incidents as related in a recent publication, which I think will be found of interest. It seems that after a long time, and much labor, he succeeded in producing a very elaborate and costly stamp, which required skillful workmen and elaborate machinery, such as only the Government could afford to make. It was at last proved to the satisfaction of the stamp department that by its adoption, and by securing the services of the inventor to superintend their manufacture, the revenues of that department would be largely increased. At last, after much time had been consumed by the negotiations, an arrangement was perfected, by which both his stamp and his services were secured to the Government.

It seems that he was at this time engaged to a young lady, and was only waiting to obtain this position, or, as we say, "the stamps," in order to be in a position to marry her. Feeling that the consummation of his hopes was now near at hand, he went to pay a visit to his intended, and believing that she would be equally interested in the invention, which would add so much to their future happiness, he took with him a sample

of the stamps he had designed, and explained to her what were the difficulties to be overcome, and how he had succeeded in overcoming them. He explained that one of the most desirable things to be accomplished was to so make the stamp that it could not be used more than once. As the young lady looked at it she said, "If you could print the date on it, that would prevent its being used again." The idea struck him that he could make the die so as to insert movable type, so that the date might be changed daily. He at once changed his device; but little did he or the young lady dream what would be the result of the improvement. Mr. Bessemer, relying upon the good faith of the Government officials with whom he had so long been negotiating, took his new and improved stamp to them for their inspection; and to the credit of the Government be it said that they at once saw the value of the improvement, and what was more, they also saw that by adopting it they could use their old stamp dies, and could also do without any stamp superintendent. So they coolly adopted the plan, and as coolly ignored the invention and the inventor, and, as he afterwards said, "I had no patent to fall back upon, and I could not go to law if I had wanted to do so, for my money was all gone; so, sad and dispirited, and with a burning sense of injustice overpowering all other feelings, I went away from the stamp office, too proud to ask as a favor that which was undeniably my right."

This failure did not, however, discourage him from making further inventions, the history of which reads like a romance. At one time having occasion to use some bronze, he was struck with the vast difference between the cost of the raw material and the manufactured article. He made inquiry as to where and how it was made, and he learned that it was made in Germany, but could learn nothing as to how it was made; but he began a study of the subject, and after 18 months of faithful trial he gave it up as hopeless. After a rest of six months, however, he began it again, and soon after hit upon a successful plan. Mindful, doubtless, of his former experience, he did not show his invention to any one; he had the machinery made in various parts of the country, and then ran it in a room into which no one was admitted. As fast as he could make the bronze, he found a ready sale for it; and as his profit at first was a thousand per cent., he was soon able to build several machines, and as the business grew to such an extent that he could not attend it alone, he selected four or five assistants who, he thought, could be trusted, paid them very high wages, and for over 25 years this secret manufacture was continued in good faith. About 12 years ago he turned over the entire business to the two surviving workmen who had so faithfully aided him through so many years, and up to the present day the manufacture of the famous "Bessemer gold paint" remains a secret.

There is one other invention I desire to refer to, previous to the great invention with which his name is best known. I refer to it not so much on account of the invention itself, as on account of the surrounding circumstances, which led me to think that Henry Bessemer must have been the person whom Charles Dickens had in mind when he delineated the character known as "Daniel Doyce" in "Little Dorritt," and his dealings with the Government must have suggested that wonderful history of that wonderful "department," which Dickens called the "Circumlocu-

tion Office." The invention which gave the "Sir Tite Baracles" of that office so much trouble, was an improvement in ordnance and projectiles. This was at the time of the troubles between England and Russia, which finally culminated in the Crimean war, and it was during the time of this war that the "Circumlocution Office" arrived at its highest eminence, and when the art of "how not to do it" had been learned to its greatest perfection. Mr. Bessemer invented what he considered a valuable improvement for the purpose of rotating the shot and shell, when fired from a smooth bore gun. I cannot go into a full account of the invention, but after a long and tedious waiting he obtained a hearing before the authorities at Woolwich arsenal. The officials gave the matter but slight attention, and simply ridiculed the idea of any one outside of the "department" meddling with affairs of that kind. Or, as Charles Dickens, in his inimitable manner, when describing this, or a similar event, makes Mr. Meagles, in speaking of Daniel Doyce's experience, to say: "How, after interminable attendance and correspondence, and infinite impertinences, ignorances and insults, my lords made a minute numbers three thousand four hundred and seventy-two, allowing the culprit to make certain trials of his invention at his own expense; how the trials were made in the presence of a board of six, of whom two ancient members were too blind to see it, two ancient members were too deaf to hear it, one other ancient member was too lame to get near it and the final ancient member was too pig-headed to look at it."

Not long afterward, quite disgusted with the treatment he had received from his own country, he went to Paris, where, at a dinner party, he met Prince Napoleon, who, on inquiring about the invention, became very much interested in it, and asked Mr. Bessemer to show it and explain its merits to the Emperor, which he did soon after. The French Emperor became greatly interested in Mr. Bessemer's explanation of his invention, and he urged him to continue his experiments, and at the same time placed in his hand a sum of money to defray the cost of them. Some time after, when Mr. Bessemer had built a gun and with his improved projectiles proved to the French military authorities the value of the invention, a general who witnessed the trial said: "Yes; the shot rotate properly, but if you cannot get stronger metal to make your guns of, the shot will be of little use." It was this incidental remark, made by a French officer, that first turned the thoughts of Mr. Bessemer into that channel the following of which has produced the most marked change in metallurgy that the world has ever witnessed.

Mr. Bessemer immediately returned to England, made a tour of the principal iron works and began a study into the process by which iron and steel were produced. He then began experimenting in a small way, seeking to improve iron in various ways, but without much success; he built up one furnace after another, only to tear them down again. This continued for a year or two, until at last the idea came to him to try to purify iron by blowing air through it while melted. He first began by melting 8 or 10 lbs. in a crucible, and blowing air through it by means of a movable blow-pipe. He found that he could make good iron, but that was all; but it encouraged him to go on. He then built

a small furnace, or cupola, which was open at the top, and had a number of small holes through the bottom, through which he was to blow the air. He had it heated up and hung over it by a chain a round lid such as is used to cover holes in the side walks. When all was ready, he told his workmen to pour the melted iron into the top of the furnace and on to the air, and then to drop the lid on the opening. The men turned the metal in, but when it struck the air that was rushing in at the bottom, it produced such a frightful roar and so filled the whole place with flame and sparks, that the men fled to save their lives. As the air cock was close to the furnace no one could get near enough to it to shut it off, and so it roared and blazed away undisturbed. Soon the lid that hung over the mouth got hot, and, melting away, dropped down into the fiery mass. As they looked on in amazement, they observed a change in the color and in the fierceness of the flames, until in a short time it died down so that they were able to get close enough to shut off the blast and stop the process. When the furnace had cooled down, they examined the metal, without having the slightest idea of there being anything peculiar about it, but a close scrutiny revealed the fact that it was not iron—it was steel. Thus all at once, by what seemed to be a most undesirable accident, there leaped into existence the most wonderful transformation of metals the world had ever seen or known ; and had the wildest dreams of the most studious alchemist of the olden time come to pass, it could not have equaled what Henry Bessemer had accomplished that day in the old house in which Richard Baxter once lived and wrote.

While Bessemer had, as it were by accident, made steel by blowing air through melted cast-iron, he was a long way from having made it an engineering or a commercial success, and he traveled a long and rugged path ere that was accomplished. That at last it was so made is in part due to the skill and ingenuity of an American engineer, Alexander L. Holley.

Eighteen years ago, in company with A. B. Stone, then President of the Cleveland Rolling Mill Co., I visited Troy to examine the only Bessemer steel plant then in the United States, and just how small and insignificant an affair it was, I have not now time to tell. The Cleveland Rolling Mill Co. had decided to build a steel works in Newburg, under the Bessemer license. They employed as the constructing engineer Herr Gemlin, a German engineer of marked ability, who had lived in England for a short time, and had made the process a study at Mr. Bessemer's works. The Cuyahoga Works of this city, with which I was then, as now, connected, undertook to furnish the necessary blowing engines, steam boilers, hydraulic cranes, and other machinery; and it is a matter of congratulation to all concerned to be able to say that no steel works built before or since, of the same size and capacity, have equaled the Bessemer steel plant at Newburg in the quantity of steel produced. The works were completed and were ready for trial on September 6, 1868, and now, after nearly 16 years have passed, as I look over my notes I vividly recall the first "blow" and its results. As there was at that time no one in this country who had had any experience in making steel by this process, the Rolling Mill Co. brought from England two

men who had worked for Charles Cammels & Co., Sheffield, England, to superintend the blowing. Whether it was owing to the difference in the iron, as compared with what they had been accustomed to, or not, I cannot say, but for some reason the first "blow" was a miss. The making of steel by the Bessemer process was at that time an experiment, at least in this country, and it claimed results so widely different from what had been done previously, that it had awakened a great deal of interest among engineers and iron and steel makers. Inasmuch as I had never witnessed the operation, I took careful note of every movement, and made memoranda of the same at the time; and I find by referring to them now the following;

Sept. 6, 1868. Began to charge the air furnace with four tons of pig-iron, being a mixture of Tilden, Fayette Brown and Hanging Rock charcoal iron.

The first pig went in at 1:15 P. M., and at 1:25 all the metal was in the furnace, the blowing engine running slowly to heat up the converter.

At 3:30 the spiegel furnace was charged with 700 lbs. of German spiegel.

4:34, air furnace tapped, and at 4:35 the metal was all in the converter.

Blast turned on, and vessel turned up at 4:39. Engine was running 30 revolutions per minute, air pressure 25 lbs., steam pressure 70 lbs.

At 4:53 slowed the engines and dropped the blast to 15 lbs., and at 5:28, after blowing 49 minutes, the vessel was turned down and the blast shut off.

5:30, the spiegel furnace was tapped, and the metal from it run into the converter.

At 5:35 the 15 ingot moulds had all been poured full; about as much more had been run into the pit, and the ladle was not yet empty.

The whole affair, while being a most magnificent display, was also a profound mystery as well, and the greatest puzzle of all was, how it happened that there was so much more metal after the blow than before; but as no one but the two Englishmen knew anything about it, and as those two imported blowers were exceedingly reticent, I came away as much puzzled as ever. The next day, on making inquiry as to the *quality* of the steel produced, I was informed that, on examination of the ingots after they had cooled down, it was found that there was not a single pound of iron or steel to be found anywhere; the metal had been so tremendously over-blown that it had all been burned to a cinder. The two Englishmen in charge of the blowing soon became familiar with the metal and plant, and produced very good steel; but for some reason they did not remain long, and after their return to England another event happened which was also a puzzle to me—which was, that a man whom we had in our employ as a machinist, and who assisted in setting up the blowing engine and had remained to run it, and a farmer living in the vicinity were selected to blow the steel in their places, and up to a very recent date, if not now, they are still doing it. The immense quantity of steel turned out at the Newburg works was made under the direction and charge of two men who never before in their lives had seen the inside of a steel or iron works of any kind.

As to the chemistry of the process, I can only briefly say that the end desired is to remove from the cast-iron as many of its impurities—such as silicon, carbon, sulphur, phosphorus, etc., as is possible. Ordinary cast-iron contains from 2½ to 5 per cent. of carbon, and from 1.75 to 3 per cent. of silicon, and the less it has of the other two ingredients the better steel it will make. Silicon has a great affinity for oxygen, and it is the union of the two which produces the enormous heat in the converter when the air is blown through the metal. The carbon oxidizes in the last stage, and a close observation of the flame denotes the time when it disappears entirely. When this takes place the vessel is turned down, and as the carbon is all burned out, there remains simply a mass of pure iron. Now, as steel must have a certain portion of carbon, varying according to the purpose for which it is to be used, this must be added, and this is called recarbonizing the metal. This is done by adding after the "blow" a peculiar iron called spiegel, or spiegeleisen, which has a known quantity of carbon as well as a portion of manganese in its composition. The manganese unites with the oxide of the iron and passes away with the slag, while the carbon remains and converts the iron into steel. When Mr. Bessemer began to make steel at first, he undertook to stop the "blow" at a point just before the carbon was all burned out, and thus leave in the converter exactly the quantity necessary to make steel of the required carbon; but it was exceedingly difficult to stop the "blow" exactly at the same point every time, the plant had to be abandoned on account of the want of uniformity in the metal, and the plan of recarbonizing was adopted; and it is but just to say that this is claimed by Robert Mushett as his invention.

As an illustration of the wonderful increase in the quantity of steel produced in later years at Newburg, as compared with what they did at the first, and as compared with what all the steel works in England were also doing at that time, I have recently obtained some data that will be interesting. The Newburg plant then consisted of two 5-ton converters. After the works had been running some time they succeeded in getting 5 "blows" in 12 hours; and if by any fortunate combination of circumstances they at any time managed to get an extra "blow" in, the workmen immediately employed their remaining breath in blowing the foam from a keg of beer with which it was usual to celebrate so extraordinary an event. Of late years, owing in part to improvements made in various details, and in the more rapid handling of the material, as well as to the care taken to prevent any delays due to the workings of the vast machinery employed—which I may say has been under the able supervision of our member, Mr. E. H. Martin, for many years—and perhaps more than all else to the wonderful energy, push and *esprit de corps* infused into all departments by that remarkable manager, the late Henry Chisholm, the product of this very same plant of two 5-ton converters has been made to yield 65 and sometimes as high as 79 "blows" in 24 hours, each of which converted 8 tons of iron into steel, thus, as will be seen, increasing the output of steel from 25 tons in 12 hours to 520 or more tons in 24 hours; and, what is most remarkable, whole years have passed in which from January 1 to December 31 not a single heat has been lost owing to any accident or failure of the machinery.

While I did not, and do not, intend to go into the history of the steel works in this country in general, I cannot but avail myself of this opportunity of expressing my belief that the rapid progress and remarkable result in the American steel works generally, are due to the ingenuity, industry and skill of American engineers, at the head of whom stood Alexander L. Holley. He did away with the deep pit used in the English works; he built improved hydraulic cranes, located them where they could be better employed, substituted the cupola for the reverberatory air furnace, added removable bottoms to the converters, and in numerous other ways arranged the old appliances and added new ones by which not only more work could be accomplished, but by which it could be done more easily and cheaply. To do this not only involved a good deal of hard study, but it involved the making of a good many contrivances which, to be successful, had to be tested and improved by trial. While, as I have said, the credit of these improvements in the main is due to Mr. Holley, it will never be known just how much he was indebted to his numerous friends for aid, counsel and advice. So free himself to give advice and assistance to others, it is not strange that he found here and there throughout the country men of long experience and of great mechanical ability who, charmed with his genial and frank manner, were but too glad to welcome him to their homes and firesides, there to sketch, and talk, and plan all kinds of devices by which to accomplish some desired result.

Permit me to add in passing, that it is greatly to be hoped that in the forthcoming "Life of Holley," now being prepared by his near friend and neighbor, Rossiter W. Raymond, we will find mention made of at least a few of those able metallurgists and engineers who in various parts of this country were his counsellors as well as his confidants. Sitting not long since at the fireside of a most genial couple, the gentleman a famous engineer and the head of a large iron and steel works, I was greatly interested as I listened to their reminiscences of Holley, and I could easily imagine what the past had been to them; and when they told me that in building their new home, a room had been set aside and furnished for Holley, the lowered tone and steadfast gaze upon the gray ashes on the hearthstone, told more than words could of anticipated pleasures, never now to be realized. It is well known that often when sore perplexed by some puzzling problem in connection with his steel works, Holley would leave his office in New York, take a train for some distant place, pass a day or two with some of his iron and steel making friends, where, seated in the yard on a pile of blooms or some equally convenient place for chalking it out, they would go over the matter together, and by an interchange of ideas some plan would be thought of that would accomplish the desired result. Speaking of sitting on a "pile of blooms" and as a further illustration of the "rapid process" as practiced in this country, it is said of Holley that once as he was showing an English steel maker about his works, and explaining the various improvements by which steel was in this country made so rapidly, his English friend, surprised and charmed with what he saw, but perhaps unable to take it in as fast as it was told him, said : "Holley, I would just like to sit down here on an ingot and watch the works all day

long." "Well," said Holley, "if you wanted to sit on an ingot, you would have to bring one from England, for in this country you could not find one cool enough to sit on."

In the visit of the Club to witness a "night blow," which we have in contemplation, there may be some who have never as yet witnessed such a scene. To prepare such for what awaits them and illustrate as well the poetry and imagination of one who has made a world-wide reputation as an earnest worker, and a successful engineer, I will close with a description of a "blow at night" written by Alexander L. Holley for the Troy *Daily Times* in 1865 :

"The cavernous room is dark, the air is sulphurous, the sounds of suppressed power are melancholy and deep. Half-revealed monsters, with piercing eyes, crouch in the corners ; spectral shapes ever flit about the wall, and lurid beams of light anon flash in your face as some remorseless monster opens its red-hot jaws for its iron ration. The melter thrusts a spear between the joints of its armor, and a glistening, yellow stream spurts out for a moment, and then all is dark once more. Again and again he stabs it, till six tons of its hot and smoking blood fill a great caldron to the brim. Then the foreman shouts to a thirty-foot giant in the corner, who thenceforth stretches out his iron arm and gently lifts the caldron away into the air and turns out the blood in a hissing, sparkling stream, which dives into the white-hot jaws of another monster—a monster as big as an elephant, with a head like a toad, and a scaly hide. The foreman shouts again, at which up rises the monster on its haunches, growling and snorting with sparks and flame. What a conflict of elements is going on in that vast alboratory, a million balls of melted iron tearing away from the liquid mass, surging from side to side and plunging down again only to be blown out, more hot and angry than before; column upon column of air squeezed solid like rods of glass by the power of five hundred horses, piercing and shattering the iron at every point, chasing it up and down, robbing it of its treasures only to be decomposed and hurled out into the night in roaring blaze. As the combustion goes on, the surging mass grows hotter, throwing out spashes of liquid slag, and the discharge from its mouth changes from sparks and streaks of red and yellow gas to thick, full, white, dazzling flame. But such battles cannot last long. In a quarter of an hour the iron is stripped of its every combustible alloy and hangs out the white flag. The converter is then turned down on its side, the blast shut off, the recarbonizer run in. Then for a moment the war of the elements rages again; the mass boils and flames with higher intensity, and with a chemical reaction sometimes throwing it violently out of the converter's mouth; then all is quiet, and the product is a liquid, milky steel, that pours out into the ladle from under its roof of slag, smooth, shining and almost transparent."

A DUTY TEST OF A CAST-IRON BOILER.

By W. S. Bates, Member of the Western Society of Engineers.
[Read June 17, 1884.]

I was recently called upon to investigate the efficiency (or rather the inefficiency) of a steam heating apparatus. In the course of my investigation I found it necessary to make a duty test of the boiler. Cast-iron boilers are seldom, if ever, subjected to a duty test. I do not know of a single such test on record, and this is my excuse for bringing this one before you to-day.

The boiler in question was a cast sectional boiler, of the Walker-Pratt type, with 28 sections. It was of the following dimensions :

Size of grate	12.00 sq. ft.
Heating surface	426.66 " "
Ratio heating surface to grate	35.55 to 1.
The area of top return was	312.00 sq. in.
" " " main " "	333.87 " "
" " " connecting flue to stack	176.71 " "
Middle return flue is	19.33 per cent. of grate.
Connecting flue is	10.21 " " "
Middle return flue is	0.54 " " heating surface.
Connecting flue is	0.29 " " " "

The average thickness of the iron was about 5-16 inch.

The test was made in the usual manner—that is, the boiler having been first cleaned and put in good shape, and steam got up to the required pressure, the fires were drawn and as quickly as possible rebuilt with weighed fuel. At the end of the test the fires were drawn and spread out on the floor, extinguished as quickly as possible and picked over, and the unconsumed coal deducted from the coal account. The feed water was weighed, and the temperature of feed and the steam pressure per gauge were noted every ten minutes. The coal used was common hard coal, and was 85.39 per cent. combustible.

The following are the data obtained, viz :

Duration of test	5 hours.
Total coal consumed	573.0 lbs.
Coal consumed per hour	114.6 "
Coal consumed per hour per sq. ft. of grates	9.55 "
Total of water evaporated	3,147.0 "
" " " per hour	629.4 "
" " " " per sq. ft. of heating surface	1.475 "
The average pressure per gauge	10.14 "
Average temperature of feed	55.44 deg. F.
The evaporation per pound coal from temperature of feed was	5.49 lbs.
The equivalent evaporation from and at 212 degrees and atmosphere	6.43 "
Do. do. per lb. combustible	7.53 "
Per cent. of total heat developed, utilized evaporatively	50.2 "

(1 lb. carbon equals 14,500 units, equals 15 lbs. water per pound.)

It is of interest to compare this boiler with a good tubular boiler, and for

this purpose I will take the boiler of the Saratoga Water Works, of which I happen to have the data at hand.

These Saratoga boilers are of the horizontal return tubular type, 66 inches by 18 feet, with 87 3-inch tubes, 28.5 sq. ft. of grate surface, and 1,478.75 sq. ft. of heating surface.

Ratio of heating surface to grate, 51.89.

Sectional area of tubes (aggregate), 615.09 sq. in.

Sectional area of tubes is 15.68 per ct. of grate.

Do. is, 0.29 per ct. of heating surface.

These boilers gave 1.19 lbs. steam per square foot of heating surface, and evaporated 11.65 lbs. water per lb. combustible fr. 212 deg, at 0 gauge.

The coal consumed per square foot of grate per hour was 5.92 lbs.

This is 77.66 per ct. of the total heat developed, utilized evaporatively against 50.2 per ct. in our cast boiler, or a deficiency of 35.3 per ct. in the latter.

What is the cause of this deficiency in the cast boiler? On comparing the dimensions of our two boilers and taking the heating surface as the unit, we find that the grate of the tubular is 1.93 per cent of the heating surface, whilst the grate of the cast boiler is 2.82 per cent of the heating surface, or 45.6 per cent larger in proportion than the tubular.

The return flue area of the tubular is 0.29 per cent of the heating surface, whilst the first return of the cast boiler is 0.57 per cent of the heating surface, or 96.5 per cent greater in proportion than the tubular, from which it would appear that if our grate surface and our flue area were both diminished we would obtain better results. But boilers of substan tially similar proportions of grate and heating surface and flue area have given much better results. For example, Isherwood reports the boiler of the United States steamship *Wyandotte* as giving 11,983 lbs. steam per pound combustible from and at 212 degrees. It was a vertical water tube boiler of the Martin type, with a grate surface of 2.69 per cent of the heating surface, and a flue area of 0.5 per cent. of the heating surface. These proportions are very nearly the same as those of our cast boiler, but show a slightly larger heating surface in proportion, and the coal consumption was 10.363 lbs. per sq. ft. of grate per hour, or a little more than in our cast boiler.

From which I conclude that the deficiency of our cast boiler is due partly to its bad proportions and partly to its general design.

THE SIGNAL SERVICE AND ITS RELATION TO THE INDUSTRIES OF THE COUNTRY.

By G. A. Hyde, Member of the Civil Engineers' Club of Cleveland.

[Read March 11, 1882.]

The subject of the few remarks I shall offer this evening is, Should the United States Signal Service weather bureau be continued and its operations extended?

I am not desirous of forcing on your attention the much-discussed weather, for there is no one subject that is more frequently referred to; but I trust that I may, without annoyance to the most fastidious or without being accused of riding a hobby, call your attention for a few moments to the doings of the Signal Service of the War Department, the import-

ance of its permanent establishment and the desirableness of a better acquaintance with the subject of its operations by the general public.

It has been about twelve years since our government established this service for the purpose of studying and making forecasts of the weather, and about forty years since Prof. J. P. Espy established a system of volunteer observations to determine the character of the storms of our country.

The utility of this service has been continually demonstrated by the predictions sent out by the signal officer since its establishment. Great numbers of vessels and hundreds of lives have undoubtedly been saved from destruction on the lakes and ocean by observing the warnings given by this bureau, and multitudes of people on land have found it profitable to conform their business and pleasure to the weather probabilities.

The Signal Service has stations established at many important points all over the country, at which signals are hoisted to give warning of the approach of severe storms; bulletins are posted at prominent points in the principal cities, giving daily the condition of the weather throughout the country; and the daily newspapers contain the signal officer's predictions of the weather for the day. Mariners in and near port, and people in and near the cities and large towns, have access to these means of obtaining the weather predictions and can gain profit or be secured from loss by conforming to them. A great many people make practical use of this information. But the mariner away from port, and people living in or about the country towns, have not yet the facilities for gaining this information. The present system should be largely extended, so that signals could be given at many more prominent points on the shores of our Great Lakes and on the Atlantic Coast.

There is great need of practical knowledge, by people in general, of the theory and characteristics of the great storms that traverse our country and the method of predicting their approach by the use of the barometer, the condition of the atmosphere and the appearance of the sky.

This information and suitable instruction can be the most easily and correctly furnished through the Signal Service.

A vast amount of meteorological information has been obtained by the investigations made during the past fifty years, and a great good accomplished to compensate for the great expense and the patient and persistent labor of paid and volunteer observers; but it is hoped that still greater advancement can be made by careful and untiring investigation.

But the extensions of the operations of the Signal Service will require the annual expenditure of a much greater amount of money than at present, and Congress, which should have in view the best interest of our whole country, can authorize the incurring of any expense necessary to perfect this system, and should be thoroughly awake to the importance of this great enterprise. An important auxiliary in securing the attention and interest of Congress in this matter is the expressed interest of those who are acquainted with the benefits its operations confer on the community. The Signal Service has many friends but needs more, and my object in making these remarks is to awaken an interest in and request of each member of this club a personal acquaintance with the operations of the Signal Service, and if opportunity presents or occasion requires, speak a favorable word for and give their influence in favor of its permanent establishment as a branch of the Government Service, and the liberal extension of its benefits to every portion of our great and prosperous country.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

JULY 1, 1884 :—The 189th meeting was held at the Society rooms at 4 P. M , President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Liljencrantz, for the committee appointed to design and procure more book-cases, requested that an additional member be appointed on this committee. The Chair appointed Mr. Morehouse as a member of this committee.

On motion of Mr. Benezette Williams, the Secretary was requested to send to each member a few blank applications for membership, with the request that each member endeavor to induce friends or acquaintances, eligible as Members or Associates, to connect themselves with the Society.

It was voted that a committee be appointed to revise the constitution and by-laws. The Chair appointed Messrs. Liljencrantz, Artingstall and Wright as this committee.

Mr. Cregier offered the following as an amendment to the by-laws, to amend Section 8, Article IV., by adding these words :

"Any member who shall have paid his dues consecutively for a period of twelve years shall thereby become a life member, and thereafter be exempt from all further dues."

This was referred to the Committee on Revision.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

JULY 15, 1884:—The 190th meeting was held at the Society rooms at 4 P. M , President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted as a member was presented from Mr. John Allison Porter, tunnel engineer, consulting engineer and draftsman, residing in Chicago. The application was indorsed by Messrs. Wright, Morehouse and Cregier.

Mr. Wright, for Committee on Revision, reported progress, and requested more time, which was granted.

Mr. Wright, for Committee on Transportation, stated that this committee had a paper for presentation, "Stable Construction," prepared by himself.

The paper was read, and after having been discussed, it was voted that it should be printed.

Mr. Cregier explained the manner in which the river commerce of Chicago would be transacted after the present draw-bridges were abolished and fixed spans substituted for them.

After a general discussion of this matter the meeting adjourned.

L. P. MOREHOUSE, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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EVOLUTION OF THE ELECTRIC RAILWAY:

ITS COMMERCIAL AND SCIENTIFIC ASPECT.

BY DR. WELLINGTON ADAMS, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read April 23, 1884.]

Since Denys Papin, in 1687, proposed the transmission of power over long distances pneumatically, human genius in every age and clime has been struggling to solve the problem of power transmission in accordance with the principles of economy.

It is primarily the more desirable to effect this, that advantage may be taken of the various forces of nature, such as the ebb and flow of the tide, swift-running streams and waterfalls, for the performance of work at points located awkwardly or at some distance from the source of power.

Furthermore, since the advent of the steam engine, the economy attending the centralization of power and its distribution to isolated consumers, even when thus artificially developed, has been fully recognized by all engineers. Various methods have been proposed for accomplishing this; such, for instance, as pneumatic, hydraulic, cable, and steam transmission. But all have thus far failed to practically meet the requirements, until now electricity has entered the field as a contestant, and seemingly put an end to competition ; since it has been both *theoretically* and *practically* demonstrated beyond question by a host of noted scientists, some of whom have the honor of being recognized as among the greatest living engineers—such for instance, as Sir William Armstrong, Sir Frederick Bromwell, Dr. Werner Siemens, Sir William Thomson, Prof. John Perry, Profs. Priece and Ayrton, M. Marcell Deprez, Count du Moncel, and many others of like scientific celebrity—that electricity may be used as a medium of power transmission with greater facility and economy, all things considered, than any of the other known methods.

It is the invention of the dynamo-electric machine that has rendered possible this method of power transmission. Such a machine yields electricity as the result of rotation imparted to it by the expenditure of mechanical power derived from some natural or artificial source. A portion of this power may be reclaimed by causing the electric current

generated in one dynamo-machine to circulate through a second similar machine. Hence, all dynamo-electric machines—the name signifying from mechanical motion to electricity—become electro-dynamic machines when the condition of affairs is reversed, and an already existing current of electricity is caused to circulate through them. The second or reclaiming machine, or translating device, as some call it, will, when a "series wound" machine, rotate in an opposite direction and deliver up a certain proportion of the mechanical power expended upon the pulley of the first. This constitutes the basis of the electrical transmission of power. These facts are generally admitted to have been first pointed out and demonstrated by Messrs. Fontaine and Gramme, at the Vienna Exhibition of 1873; although Pacinotti had, in 1861, constructed a motor identical in principle with the modern dynamo-electric machine, and clearly pointed out its reversibility. Considering this question of electric transmission of power from its two principal standpoints—first, as regards the electric current developed from the mechanical power (the steam engine for instance); and, second, as regards the amount of mechanical power reclaimed from this current at the distant point through the instrumentality of an electro-dynamic motor, the efficiency of the system is 70 per cent., allowing 7 per cent. for loss by leakage in and resistance of the connecting conductor. The amount of energy lost by the two conversions from mechanical motion into electrical energy, and from electrical energy back again into mechanical motion, is a fixed quantity, and practice has demonstrated this to be 13 per cent. from the first and 10 per cent. from the second process, when the most efficient types of electric generator and electric motor are used.*

The other element of loss—that by leakage in and resistance of the connecting conductor—will naturally vary with the conditions in each individual case, and will depend entirely upon the size and insulation of the connecting conductor. In general it will, in my opinion, be best to base a calculation upon a 7 per cent. loss in the conductor, allowing 5 per cent. for resistance and 2 per cent. for leakage. This, however, will be governed entirely by the peculiar conditions attendant upon each individual case. The rule given by Sir William Thomson is to the effect that the most economical diameter is secured when the two losses (that is, the loss from heating and the interest upon the price of the conductor) are equal. Knowing the cost of one horse-power of electrical energy in any particular locality, which depends upon the price of coal and the efficiency of the machinery used, and the cost of copper per ton, and remembering the formula $H = \frac{C^2 R}{746}$, the calculation for that locality may be readily made. Assuming, however, the loss in the conductor to be 7 per cent., and the loss in each of the translating devices to be 10 and 13 per cent. respectively, the total loss by transmission becomes 30 per cent.; or, in other words, 70 per cent. of the power expended at the point from

* The lecturer here demonstrated the electrical transmission of power, by means of two dynamo machines of about 1½ horse-power each; and also by means of two Holtz machines—one acting as generator, the other as a motor. The electric motor used upon this occasion had been continuously and successfully running the machine-shop connected with Dr. Adams laboratory for over a year.

which the distribution is to take place, may be recovered in the reclaiming machines or electric motors. That is to say, we may deliver within reasonable distances just $\frac{7}{10}$ of the power expended in the first instance. For example: a steam engine of 500 horse-power operated at a central station in the centre of a ten-mile circuit, could by the aid of an electric current traversing a suitable conductor, lay down $\frac{7}{10}$ of its power or 350 horse-power distributed among as many different points within that circuit. The fact must here be borne in mind that, aside from all considerations of nuisance and cost of services of engineers, this 500 horse-power may be generated in a single engine for one-fourth the cost, in the way of fuel alone, of generating the power in small engines. Consequently, while we lose 30 per cent. of the power by this two-fold conversion and transmission, we more than make up for such loss by this one item—the gain in point of economy of fuel from the saving effected by the generation of our power in one or two large engines as compared with the cost of developing the same power in a number of small engines. Other than this, however, there are very many more important sources of economy and advantages attendant upon the centralization of our forces. Such an amount of reclaimed power is far in advance of that obtained under similar conditions with compressed air, pulleys and shafting, cables and steam, and approaches the theoretical efficiency of hydraulic transmission as advocated by Sir William Thomson, with the fact in favor of electricity that it possesses the unparalleled advantage of being almost entirely untrammeled with the obstacles presented by distance, while it is at the same time remarkably portable and capable of having its direction and intensity changed at the will of a child. No force can be detected in the connecting portions, that is, in the conductor, such as appears during mechanical transmission with shafting and cables or in pipes with compressed air, steam or water. The conductor is clean, cold and does not move, appears inert and can be shifted, bent or moved in any manner with the greatest facility while transmitting many horse-power. The primary source of power and the point of reclamation may be relatively situated most awkwardly, for the electric conductor, which is simply a copper wire, may be brought round the sharpest corner or carried through the most elegantly appointed private room conveniently and without any manner of annoyance or danger. A conductor carrying many horse-power through a room may be rendered imperceptible. There is no noise, no smell, no dirt, no heat, nothing to burst or give way; and the same circuit which may be tapped to provide many horse-power can be as conveniently drawn from to work a sewing or a washing machine, a small ventilator, a table or desk fan, a domestic flour-sifter, an egg-beater, a dentist's drill, a jeweler's or dentist's lathe. So convenient a source of light power will give rise to the invention of many new devices for the mechanical performance of much of the light domestic work which now proves a bugbear in every household.

In mining and excavating operations electric transmission will prove of great value, since it involves no danger and may be carried to points inaccessible to any other form of power. For plowing by power, trials made in France show that electricity can replace steam with advantage and economy.

Table I.
Cost of 1 horse-power hour in shillings if transmitted by electricity (potential 1,500 volts).

H. P. transmitted.	Distance in metres.						Prime Mover.
	100	500	1,000	5,000	10,000	20,000	
5	0.188	0.194	0.201	0.239	0.274	0.433	Steam.
10	0.167	0.173	0.178	0.211	0.258	0.403	Steam.
50	0.156	0.161	0.166	0.190	0.227	0.353	Steam.
100	0.149	0.154	0.159	0.182	0.219	0.340	Steam.
5	0.029	0.030	0.031	0.037	0.043	0.070	Water.
10	0.022	0,023	0.024	0.030	0.039	0.059	Water.
50	0.019	0.020	0.022	0.024	0.026	0.046	Water.
100	0.017	0.018	0.019	0.022	0.024	0.042	Water.

Table II.
Cost of 1 horse-power hour in shillings, with hydraulic transmission.

H. P. transmitted.	Distance in metres.						Prime mover.
	100	500	1,000	5,000	10,000	20,000	
5	0.209	0.236	0.263	0.544	0.873	1.658	Steam.
10	0.198	0.213	0.232	0.423	0.641	1.196	Steam.
50	0.136	0.142	0.150	0.242	0.351	0.651	Steam.
100	0.135	0.141	0.148	0.239	0.345	0.570	Steam.
5	0.024	0.032	0.040	0.115	0.208	0.329	Water.
10	0.021	0.025	0.031	0.079	0.138	0.264	Water.
50	0.013	0.015	0.018	0.038	0.063	0.119	Water.
100	0.013	0.014	0.016	0.036	0.060	0.095	Water.

Table III.
Cost of 1 horse-power hour in shillings with pneumatic transmission.

H. P. transmitted.	Distance in metres.						Prime mover.
	100	500	1,000	5,000	10,000	20,000	
5	0.225	0.247	0.275	0.483	0.794	1.396	Steam.
10	0.212	0.224	0.239	0.373	0.521	0.863	Steam.
50	0.168	0.176	0.182	0.239	0.295	0.441	Steam.
100	0.167	0.170	0.174	0.218	0.258	0.375	Steam.
5	0.033	0.039	0.048	0.106	0.200	0.371	Water.
10	0.029	0.032	0.037	0.073	0.118	0.331	Water.
50	0.018	0.021	0.024	0.037	0.054	0.090	Water.
100	0.018	0.019	0.020	0.030	0.042	0.069	Water.

Table IV.
Cost of 1 horse-power hour in shillings with wire-rope transmission.

H. P. transmitted.	Distance in metres.						Prime mover.
	100	500	1,000	5,000	10,000	20,000	
5	0.094	0.122	0.157	0.455	0.868	1.899	Steam.
10	0.093	0.115	0.142	0.375	0.709	1.593	Steam.
50	0.090	0.098	0.108	0.212	0.376	0.925	Steam.
100	0.019	0.095	0.102	0.184	0.319	0.813	Steam.
5	0.009	0.016	0.025	0.104	0.207	0.406	Water.
10	0.008	0.014	0.021	0.080	0.159	0.333	Water.
50	0.008	0.009	0.010	0.032	0.060	0.134	Water.
100	0.007	0.008	0.009	0.023	0.042	0.099	Water.

From these tables the author, whose name escapes my memory, concludes that in all cases where these four systems are equally applicable, wire-rope transmission is best for distances under one kilometre (1,100 yards), and electrical transmission for longer distances.

The following curves, which have been platted from these tables, represent geometrically the relationship existing between these several methods of power transmission.

In Scotland, power obtained from a waterfall has been electrically transmitted one mile and a half with an electrical return of 85 per cent. In Prussia, France, Austria, Ireland and England, many miles of electric railway in successful *commercial* operation demonstrates the feasibility of, and the many advantages attendant upon, electric transmission ; for, as we shall see further on, this very principle of electric transmission of power to a distance constitutes the foundation of the modern electric railway, and it is here that this principle finds its pre-eminently important application.

From these, and very many other things not here mentioned for want of time, which have already been accomplished, calculations have been based, and these show conclusively that it is possible to render available at every door any desired proportion, within reasonable limits, of the

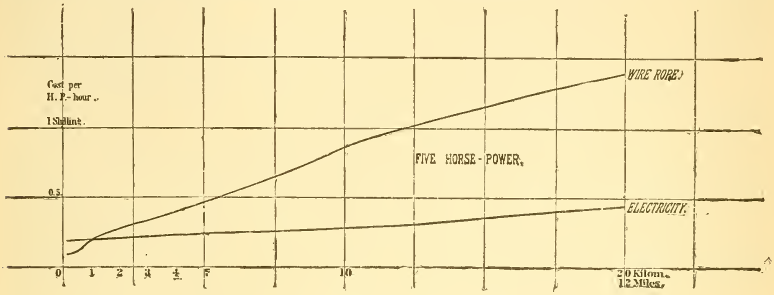

FIG. 1.

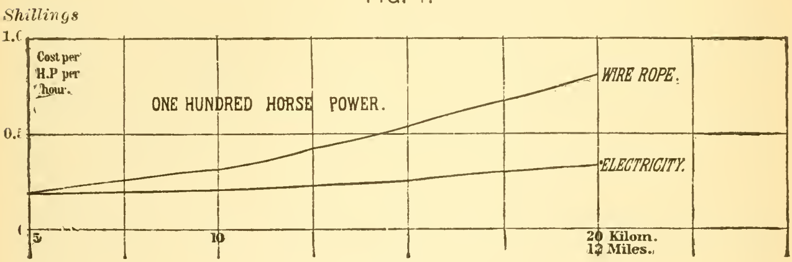

FIG. 2.

stored-up energy of our continent, in a form at once universally applicable, cheap, noiseless, cleanly, safe and manageable by unskilled hands.

All this is not only theoretically possible, but economically praticable. It is not of necessity simply a dream of a future Utopia. It may be made a realization of the present—a grand every-day commercial experience.

It only requires that engineers generally and capitalists shall become conversant with these facts, to bring about a transition from the stage of practical *demonstration* to that of practical *application*. It seems strange, perhaps, to some of us, when we consider that these things have been demonstrated facts since the beginning of the present decade, that capital has not been directed in this channel ere this. Great scientific truths, however, become popularized very slowly. They require a long

time to become a part of the current knowledge of mankind. Without doubt we all recall to mind how it was fully a century after Copernicus died before the Copernican Theory was generally accepted by even the *learned*. And again, how from the time of Hero, who clearly set forth the principle of the modern steam engine, we find no historical evidence of its application to practical purposes for many centuries. Although John Fitch, in 1785, demonstrated beyond peradventure the feasibility of steam navigation, and worked indefatigably up to the time of his death, in 1798, for its introduction as a commercial feature of our country, it was not until 1807 that capitalists, appreciating the field open to them, came to the rescue, and assisted Fulton to make steam navigation an every-day commercial success; and even so worthy a scientist as he, frequently endeavored in vain to secure pecuniary countenance from the possessors of wealth and influence. With what force the frequently reiterated assertions of John Fitch come home to us now: "The day will surely come when some more powerful man will get fame and riches from my invention, but no one will believe that poor John Fitch can do anything worthy of attention."

Let us hope the day for reproaches similar to those Fitch indulged in are past, and that capital, with its frequent similar experiences, backed by greater enlightenment and enterprise, will never again be wanting to prosecute schemes based upon scientific facts which bespeak untold wealth for their projectors and promise to confer manifold blessings upon mankind.

As I have already stated, the most important application of this principle of electric transmission of power is exemplified in the *modern* electric railway. Now, I advisedly use the expression *modern*, because the electric railway, like all other inventions, has a history. It is not a thing of spontaneous development, but of gradual growth. In considering its evolution, we must cursorily glance over the history of the "*electric engine*," as electro-dynamic machines have heretofore been christened. The earlier "electric engines" or motors belonged to that class or type known as oscillating or reciprocating engines. First to make an oscillating electric motor was a learned monk, strange to say, of Padua—Salvator del Negro, who, in the year 1831, succeeded in operating such a motor. An oscillating motor, however, has many disadvantages, the most important of which is the fact that the moving part (the "armature") at the end of its stroke is at a considerable distance from the attracting electro-magnet (the "field"). This, in electric motors, is a very serious defect, since the electro-magnetic attraction or pull diminishes in intensity very rapidly, varying, as it does, inversely as the square of the distance; so that when the armature begins to approach the field there will be very little, if any, force pulling it. Hence motors built upon this principle proved very little more than pieces of physical apparatus. The first motor for producing rotary motion by electro-magnetism, without a reciprocating action, was invented in 1833 by our now deceased countryman, Prof. Henry, late of the Smithsonian Institution, a description of which may be found in Vol. XX. of Silliman's Journal.

This motor also was but a toy, having the same defect just referred to,

as indeed did all motors brought out up to the time of the discovery of the modern "dynamo" principle. Between the time of the advent of Henry's motor and the period of Prof. Page's experiments, of which we shall learn further on, Davenport in our own country, Prof. Jacobi in Russia. Davidson in Scotland, and Mr. Henry Little in England, constructed electric motors of considerable size. Prof. Jacobi propelled a boat by electricity on the Neva, at St. Petersburg, in 1839; Davenport and Ransom Cook had quite respectable electric motors working in New York in 1840; and Davidson ran an electric locomotive in 1842 on a railroad near the city of Glasgow, Scotland. A little later, Mr. Little operated an electric locomotive in England. Jacobi's motor was of about two horse-power; that of Davidson was a little over one horse-power, and propelled a locomotive weighing five tons at the rate of four miles an hour. Excitement upon this subject reigned supreme in New York about 1841, when electro-magnetic engines became a kind of mania, and although commercially worthless, hundreds of them were manufactured to meet the market demand.

The experiments of Jacobi, Davenport and Davidson proved unsatisfactory, however, as was predicted by contemporary scientists. This, naturally, caused disappointment and reaction; so that nothing of importance was added to the stock of knowledge concerning the subject until 1845, when Prof. Page, of Salem, Mass., revived and gave to the subject a new impetus by the invention of a new form of electric engine based upon the principle of the axial force of electro-magnetism, which proved to be the most perfect electric motor ever invented up to that time. A few years later, Prof. Page proposed electricity as a motive power for railroads, through the instrumentality of his own electric engine. This engine proved so successful and attracted so much attention that the idea gained favor to such an extent as to induce Congress to appropriate and place at Prof. Page's disposal a sum of money (thirty thousand dollars) adequate to construct and operate an electric locomotive in accordance with his plans. Such a locomotive was built in 1851, and used to propel a train of cars between the cities of Washington and Bladensburg, a distance of five miles. As was natural, such an undertaking created great excitement and discussion in the scientific world, both at home and abroad, more especially because of the governmental sanction and assistance lent the enterprise. The great mathematician and scientist, Dr. Joule, and many others, very properly contended that the system would be too expensive, and that electricity as then generated, could not be used as a motive power with sufficient economy to warrant its adoption on a commercial scale. In fact it was this very discussion which led Dr. Joule to that long and laborious investigation of the mechanical equivalent of heat, which now formed the basis of all our work in thermo-dynamics, and without which we should be groping in the dark.

It was on the 29th day of April, 1851, that Dr. Page made the trial of his locomotive, which ran at the rate of nineteen miles per hour, making the trip of five miles in thirty-nine minutes. The locomotive itself weighed ten and one-half tons, including the batteries, and carried seven passengers. There were many stops and delays on account of the breakage of his battery cells, which were carried upon the locomotive, the jars

fulfilling the office of a steam locomotive boiler and furnace, zinc and sulphuric acid in the former case constituting the fuel. The sulphuric acid and zinc were burned or consumed in the production of electricity. This is the principle upon which it was sought to operate all the electric engines thus far referred to. Electricity was here called upon to serve as a prime motor, utilizing the energy stored in sulphuric acid and zinc.

The folly of such an effort is manifest, since one pound of zinc costs twenty-five times more, and is not capable of being transformed into as much dynamic force, as one pound of coal. Although Dr. Page's hopes were not realized as far as refers to the commercial aspect of the enterprise, he nevertheless accomplished a great feat, and to the day of his death he contended that the time would surely come when electricity would be economically used as a motive power upon railroads.

Ever since Dr. Page's memorable experiment, thoughtful people have been looking expectantly and anxiously forward to the fulfillment of his prophecy. The time is now ripe for such fulfillment. In fact, it has even now passed from the stage of speculation and become *au fait accompli*, many miles of electric railway, notwithstanding their primeval crudity, now being in successful operation on a commercial scale in different parts of the world.*

You ask, I imagine, "What has rendered possible at this day that which was thirty years back demonstrated impracticable; and in what respect does the *modern* electric railway differ from that of the past?"

My answer is: that which has rendered the electric railway commercially feasible, is the discovery by Messrs. Varley, Siemens and Wheatstone, and the subsequent development by many others, of the dynamo-electric machine; and the further discovery or demonstration by MM. Fontaine and Gramme of the reversibility of that machine, which admits of its being transformed into the most efficient form of an electric motor, when a suitable electric current is passed through it. The *difference* between the ancient and the modern electric railway, consists in the fact that whereas the effort was formerly made to use electricity as a *primary* motive power originating from the consumption of zinc and acid, we now use the electric engine or electro-dynamic machine as a *secondary* motor, and the electric current simply as a means of *transmitting* power procured from natural sources or previously generated by any of the known economic methods, if some natural source of power is not at hand. Such a system contemplates the establishment of a central fixed station, where large steam boilers and engines of the most economic type are erected and used to set in operation dynamo-electric machines, which generate powerful currents of electricity. These currents are in turn transmitted through a copper conductor running along the roadway, and, by means of a moving contact, they are taken up into the cars while the latter are in motion, and there passed through an electric engine or electro-dynamic machine, which operates to propel the cars. This idea of the generation by dynamo-electric machines of powerful currents of electricity at stationary points, and the transmission of these electric currents to cars while in motion for the purpose of effecting

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* Page's motor in operation and stereopticon views of the others were here introduced.

their propulsion, was first put into execution in 1879, by Dr. Werner Siemens and myself, both of us working independently and mutually ignorant of the other's doings. I constructed a small model, such as was within my limited means, and used the same to demonstrate a lecture on electricity delivered at the time in Colorado Springs, Colorado ; about the same time Dr. Siemens exhibited a more extensive model at the Paris Exposition.

In my system the method of applying the power was very different from that adopted by Dr. Siemens ; my only object then being to demonstrate the principle of electric transmission of power to a moving car for the purpose of propelling the same. On receiving news of the work of Félix and Chrétien at the sugar plantation at Sermaize, they having resorted to electricity as a source of power for plowing, I was more than ever impressed with the value of the system and of the future which lay before it, and I accordingly began experimenting upon and studying the subject up exhaustively, going thoroughly into every detail.

Although at the time actively engaged in medical practice, and connected with the Medical College in Denver, so great were the allurements, I was induced to give everything up in Colorado and leave there rather precipitately for Washington, in quest of a generic claim upon this fundamental principle. My case being examined, it was, however, found that the same principle had been *proposed* and provisionally patented, although not put in operation or even demonstrated and made public, as far back as 1840, by one Henry Pinkus, a remarkably inventive genius of that period. In 1840, however, the dynamo was unknown, and the electric car motors of Pinkus, which existed only in his imagination, were *supposed* to be operated by galvanic batteries buried in the ground. The principle of the transmission of the current to the car while in motion for the purpose of effecting its propulsion was, however, the same. The inventor even went so far as to anticipate the future use of "mechanical generators, which should be more economical" than the batteries.

Dr. Siemens and myself are consequently antedated as regards the question of first conception of this broad principle, and the underlying feature of the *modern* electric railway becomes public property. My application for a patent upon this fundamental principle is a matter of record in the United States Patent Office. This application was abandoned on discovering the record of the Pinkus patent. Appreciating, however, the rich harvest in store for inventors in this new field who should devise the most practical and economical means of applying this principle, which comprehends an army of important details, I immediately began research into the necessary conditions to a successful solution of this most intricate problem. The results of this investigation, which has cost many thousands of dollars, will, I hope, in your judgment, prove meritorious.

We may, of course, crudely mount upon a car a dynamo-electric machine of our own or another's design, and connect this up with the wheels or axles of the car by means of cog-wheels or belting, and thus effect the propulsion of the car, temporarily for exhibition purposes, regardless of the cost or of practical commercial requirements ; as

several have done since the first public exhibition of the modern electric railway by Dr. Siemens and myself, the individuals in each instance styling the result as "their electric railway," which as a matter of fact differed, figuratively speaking, but by a bolt or a nut from Siemens' original road.

[TO BE CONTINUED.]

STREET RAILROAD JOINTS.

By Augustine W. Wright, Member of the Western Society of Engineers.

[Presented September 2, 1884.]

The editor of the *American Journal of Railway Appliances* wrote: "A recent caller complained that he could not get any satisfaction out of the ordinary tram-rail 'joints;' that they were unstable, and caused battering of the rail ends and uneven riding of the cars."

We were not aware that on many of our tramway lines there was such a thing as "joints" in the rails. There are periodical breaks or spaces or interruptions or something like that, but on careful examination and recollection we do not find anything which would justify us in swearing that there were "joints." The alleged joints remind us of a story concerning a certain member of the theatrical profession, who was what is technically called by his fellows a "barn-stormer" of the "wild and terrible variety." This individual was a witness in a legal case.

Upon being sworn and asked his name he gave it as christened and when asked his profession he replied, "I am an actor," upon which every one of his comrades shouted by preconcerted arrangement, "Perjury, Your Honor, perjury!"

There is no good method known to us by which the common flat street rail can be given a good, real, substantial, durable, smooth-acting "joint." I have given much study during some years to this question. The ordinary practice of our street railroads is practically the same that was introduced upon steam railroads with the use of strap rails laid upon wooden stringers. Stevenson, in his "Civil Engineering of N. A.," 1838, speaks of the practice then in vogue of putting plates under the strap rail joints. The specifications for track laying on the Utica & Syracuse Railroad contained the following: "At each joint of the iron plate (rail) end plates shall be neatly fitted into the oak ribbons so as to bring their upper surfaces in the same horizontal plane. The end plates shall be 6 inches long, 2½ inches broad (same width as rail) and ¼ inch thick." This was prior to 1843.

When street railways for passenger service were inaugurated by the construction of the New York & Harlem in the City of New York, 1832, operated by horse-power and laid in the street, it at once became evident that to protect the general public in the use of the street, the rails should be low and offer as little obstruction as possible to the passage of vehicles. As other street railways were built the shape of the rail was fixed by ordinance. The rails have been designed in the majority of instances to serve merely as a protection to the timber substructure. They vary in size and shape and joint chairs are made to correspond. When the bot-

tom of the rail is flat plates of sheet iron have been used at joints. Also chairs of cast iron with lips on each side, top and bottom, the former to hold the rail ends in line with each other, and the latter the stringer and rails.

The common practice in this country has been merely to spike the joints, through suitable openings in the chairs, to the stringer beneath. If carefully laid this would give a reasonably smooth joint for a time, but the weight of the loaded car would press down the end of the rail

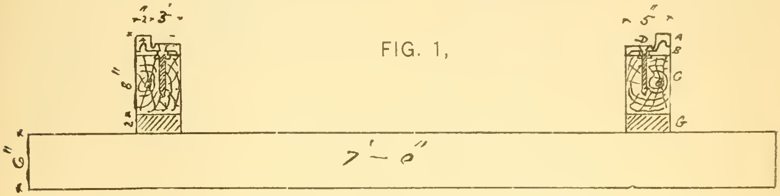


FIG. 1,

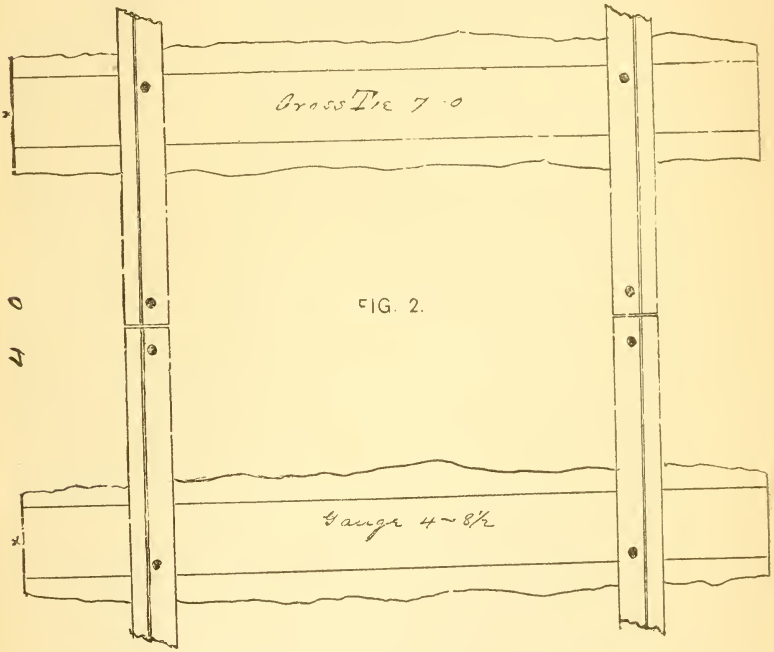
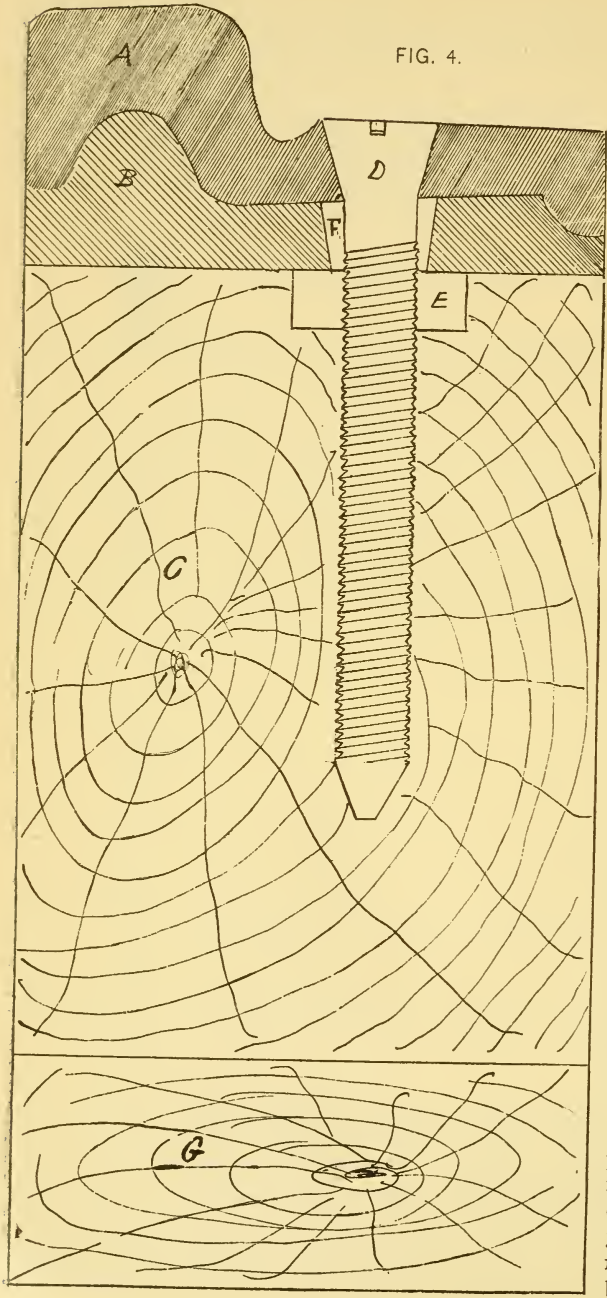


FIG. 2.

upon which it rested, and, no weight being upon the other rail end, it would project a little. The wheel striking against this projecting end, deflects it and wears a trifle from off the top of the chair and the bottom of the rail. This action, taking place upon the passage of every car wheel, soon makes a "bad joint." The chair I now show you was thus worn one quarter of an inch in four years! The spikes become loose almost from the start, and rapid depreciation follows. To avoid these discomforts to the passengers, rapid destruction of the rails, wear and

FIG. 4.



equals *three tons.* This great weight forces the chair into the wood. If an ordinary spike has been used to fasten the joint it does not follow, and the joint is then loose. This is also true of a bolt passing through the stringer with a nut beneath. The carpenter who cuts into the stringer may adz true and level and the chair be "in wind," or have slight projections upon its lower surface, so that it does not take a firm bearing upon the wood until the weight of the loaded car wheel comes upon it. In such event the joint will soon have play, and rapid wear results.

It has been proposed to fasten the rail ends to the joint chair beneath by short bolts, but this

tear on rolling stock and horseflesh, different remedies have been proposed. In foreign countries, bolts have been used, passing through the rail and stringer with a washer and nut on the bottom. Another fastening consisted of a "staple," driven into the side of the stringer, one leg passing through a suitable opening in the side of a specially designed rail. A little reflection will, I think, convince you of the inutility of such joint fastenings. In the first place, unless the timber is thoroughly seasoned, it shrinks. Condit in his work on painting quotes the measurements of Karmarsch in Germany on percentage of shrinkage of timber in seasoning: " In the direction of yearly rings pine shrinks from 5.5 per cent. to 12.7 per cent.; white pine, 4.1 per cent. to 8.13 per cent." If no other objection existed to the bolt, this would suffice, for very little, if any, track timber is thoroughly seasoned, and the shrinkage will loosen the fastening and allow a little play at the joint, to be soon increased by wear; but, as all trackmen know, the water falling upon our tracks, consisting of rain, sprinkling, etc., follows along the flat " tram-rail " until it reaches a rail joint, when it soaks through. The recess cut into the stringer for the chair beneath the rail joints serves to retain this moisture, and *this* is the first portion of the stringer to become soft and rotten. The load upon each wheel of a street railway car upon "rush" trips at time

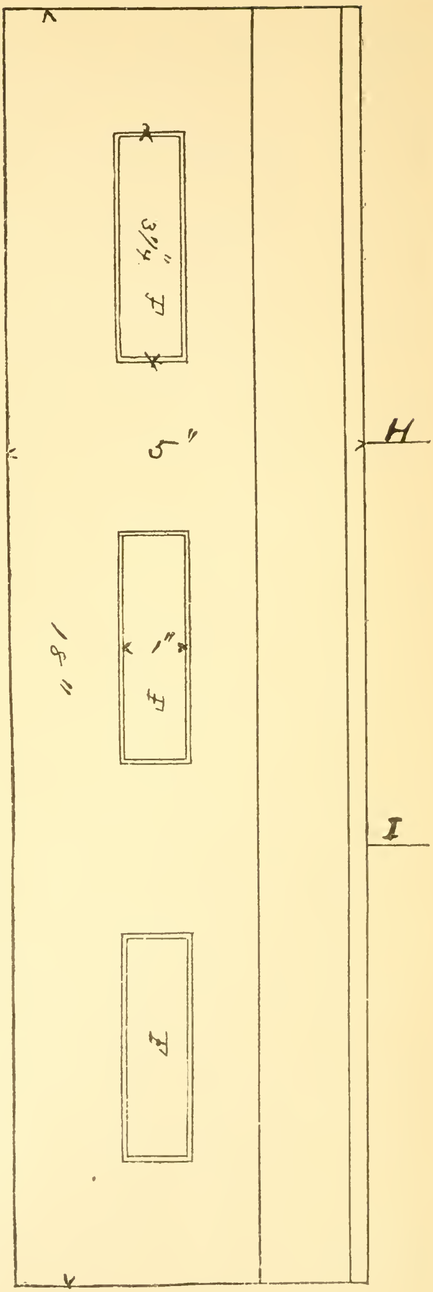


FIG. 3.

fastening, leaving the joint unattached to the timber, allows the whole joint to vibrate under passing loads and wear into the wood.

The joint I have patented, as the result of my investigation, is constructed as follows: The chairs may be steel, wrought or cast iron. Those used by me were made of cast iron. They correspond in width and shape to the bottom of the rail, five inches wide, one and a half inches deep under the head of the rail, which is rolled hollow, and five-eighths of an inch deep under tram of rail, eighteen inches long. They are let into the stringer so that their tops project one-eighth inch, and two-thirds of their length is laid *against* the traffic, on tracks where the travel is all in one direction. The form of rail and corresponding chair is immaterial. *Under the chair*, two or more nuts are let into the top surface of the stringer, flush with the latter, and beneath the holes in the rail ends. The chair is then placed over these nuts, through which holes have been bored into the stringer, less in diameter than the opening through the nuts for the bolt to pass. Suitable openings are provided in the chairs, through which these bolts pass long enough to allow the rails to expand or contract. The rail is placed on the chair and the bolt screwed through the nut into the stringer. The nut securely fastens the chair and rail ends together and prevents wear. It is longer across the stringer than it is wide, so that the wood acts as a nut lock and prevents its unscrewing by traffic vibration. The prolonged screw beneath the nut fastens the entire joint to the timber. Beneath the stringer, between it and the cross ties, at the rail joint, I put in a piece of timber two inches thick, same width as stringer, to compensate for the timber cut away for the insertion of the chair. This construction renders the joint fastening independent of all shrinkage in the wood. Should the chair sink from any of the aforementioned causes, the nuts beneath carry *both* rail ends with them and no jar results. The nut also forces the screw down into the solid wood and no vibration can take place. This joint will add to the life of the rails, for they first fail at the joint. The manager of a large rolling mill told me he thought it would prolong the rail life 10 per cent. It will save horse, flesh, requiring less power to keep a car in motion and less effort to start-for the car is most apt to stop at a defective joint. It will save the rolling stock that is wrecked and strained passing over bad joints with heavy loads, and lastly it will add to the popularity of a railroad by affording increased comfort to its patrons. I have used it in our tracks and would be pleased to have you notice Fullerton avenue or Garfield avenue. The track rides as if constructed with one solid rail. My aim has been to provide a *better joint* for the various rails now in use, without any expense that would be involved by change in them. This joint fastening is inexpensive and easily applied. In the accompanying drawings, Fig. 1 shows a cross section of track, Fig. 2 a ground plan, Fig. 3 top view of a chair, Fig. 4 section through the joint. *A* is the Chicago rail, *B* the chair, *C* the stringer, *D* the joint screw, *E* the nut fastening the rails to the chair, *F* the opening through the chair for the fastening, *G* the additional timber put under the stringer. In Fig. 3 the points *H* and *I* show where the rails join on the chair, the direction of the traffic regulating which of the two points. This figure shows the openings through the chair *F* for the fastening, allowing expansion or contraction of the rails.

THE CLEVELAND SURVEYOR.

By John L. Culley, Member of the Civil Engineers' Club of Cleveland.
(Read June 24, 1884.)

By what rule or method the vast areas of this country have been surveyed is a mystery. That the purchaser should get enough, or more, seems to have been the primary and only consideration. The surveyor of this country has rarely measured with a uniform standard, and it is a matter of wonderment that the angles between adjacent sides of a survey are ever observed to be the same, as was originally indicated by the bearings of those courses, or that any two such courses have the same proportional increased or decreased length to their original dimensions. Nor is the result to be wondered at, when we consider the tools that were used, or the training of the men who used them. They and their tools are of the days of the Jacob-staff, when angles could be read within 1° of the actual, and of the 100-link chain, which had screws at either end, for the purpose of, once in a while taking up the from 2″ to 4″ of extension.*

Moreover, though the land purchase price was calculated to the fraction of a cent, it was immaterial that the lot lines were surveyed within a rod of their correct location, or the land overran or fell short several acres of the number named in the conveyance, or how or by whom it was measured. If surveyed, it was surveyed, and though the interested party could distinguish one doctor or mechanic from another, one surveyor was as good as another, no matter how the qualifications of one compared to the other! But when the real estate became valuable, and the land underwent a process of finer measurement, the proprietor exclaimed, "Why is it that no two surveyors ever agree?" This exclamation is, of course, a fallacy. There are true and correct methods of surveying, and it is also true that by such methods land may be measured again and again with the same result. This is a progressive age and the science of surveying land lines has passed to a higher level. Each year now sees the profession doing better and better work, with more and more corrct results, and though the methods now employed are excellent, I anticipate the surveyor of 50 years hence looking back surprised at the crude methods we now use.

It is, of course, long since that land lines were determined here by those clumsy devices above referred to. Still, some two years ago, I was surprised to discover that the farms of this county were being surveyed with the same exact precision as is employed in this city. To-day the best tempered steel tapes are considered just as good for the determination of a farm boundary as for the location of a city lot line. This is an illustration of the degree of perfection the science of land surveying has reached in this city and county, and I will venture the assertion that there

* The extensive surveys of Ahaz and Adron Merchant here, are remarkably consistent and excellent, and are a grand exception to the old surveys. Unfortunately the same cannot be said of any of their contemporaries.

is no section of this country as well surveyed as is the city of Cleveland, and its adjacent country of to-day, as to the accuracy of work, the methods resorted to to render surveys permanent, and the completeness of the field notes.

It is generally admitted that instruments from the best of makers now turn angles with certainty, and that they will repeat or reproduce the true angles with equal certainty. The instrument that reads to minutes and no finer seems now to be the favorite. In actual practice the transit is kept in all its adjustments ; all lines are measured with tempered steel tapes to the nearest approximate of their absolute lengths, and the calculations are made with greatest nicety. In fact, the whole field operation is made to determine absolute results—the only basis upon which land should ever be measured. If it is to be measured at all, it should be done so most thoroughly. It cannot, however, be thus correctly measured without the most careful attention to the operations of surveying. The results should be certain and final—not guessed, neither should anything be added to or taken from them—a curse of all the old-time surveys and of those now generally being made in this country, outside of the large cities.

The measurement of the absolute length of lines is, of course, out of the question. Short distances may be measured again and again with the same result ; and they may be expected to. And this will sometimes occur to longer ones. The author has himself measured a line over 2,700 feet long, twice alike. But such results from long line measurements must be deemed accidental. Were it not for the variations due to temperature, all lines both long and short within the scope of the land surveyor could be measured exactly.

The temperature of this section during the nine months' surveying season varies from 40° to 90° F., and the vast majority of our surveys are made within the limits, 65° and 85°. We may, therefore, take 20° as the mean maximum variation. The co-efficient per 1° F. being .000007, we have the following variations :

For 500 feet	....	0.07 foot variation of length.
" 1,000 "	....	0.14 " " " "
" 2,000 "	....	0.28 " " " "

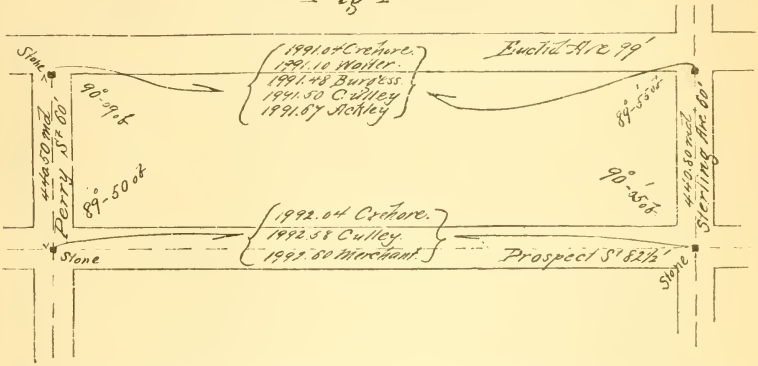
etc., and in extreme cases the variation might be four times these figures.

It is true that on days of the same temperature long lines do and should measure the same. The measurement of the 2,700 feet line proved this. In our celebrated Townsend-Holderman case was another illustration of this fact. March 5th, 1879, I found the north line of Prospect street, between Perry street and Sterling avenue, to measure 1,992.58. On the following day, not knowing my figures, C. C. Merchant measured this same line, and found it to be 1,992.60 feet—only 0.02 difference. As nearly all the leading surveyors of the city were engaged in this case, I give in Fig. 1 their several measurements of Euclid avenue and Prospect street, between Perry street and Sterling avenue.

All the measurements were made with great care and were undoubtedly correct. Their correctness has never been brought in question; not being vital to the case, none of them were challenged. Their variation demonstrates the proposition that the measurement of the absolute length

of lines is impossible. At that time I made a comparison of J. D. Crehore's and my measurement of Euclid avenue. I found his tape to be 25° lower temperature than mine, or adding 0.34 to 1,991.04 gives 1,991.38 for the measurement or a difference of only 0.12 between us, which, for the whole distance, is practically unimportant. C. H. Burgess' measurement of Euclid avenue probably was made at or near the same temperature as mine. Had wooden poles been used, the variation in these measurements would have been much less. Wooden poles require nice adjustment, for end contact, alignment, and level, and on account of the time required in their proper handling they are both clumsy and impracticable. The Chesterman patent steel tape is the most convenient and practical tape or chain yet invented for city measurements. I believe, however, that the next ten years will develop the need of the profession—a measurement of constant length. In making allowances for temperature, the fact must not be lost sight of that our measurements are made over a variety of substances, of as variable temperatures and exposures to heat or cold, and that for this reason it would not do to make too fine calculations for

Fig 1



this cause of length variations. But for the purpose of these comparisons, as well as for other purposes, every survey should be dated.

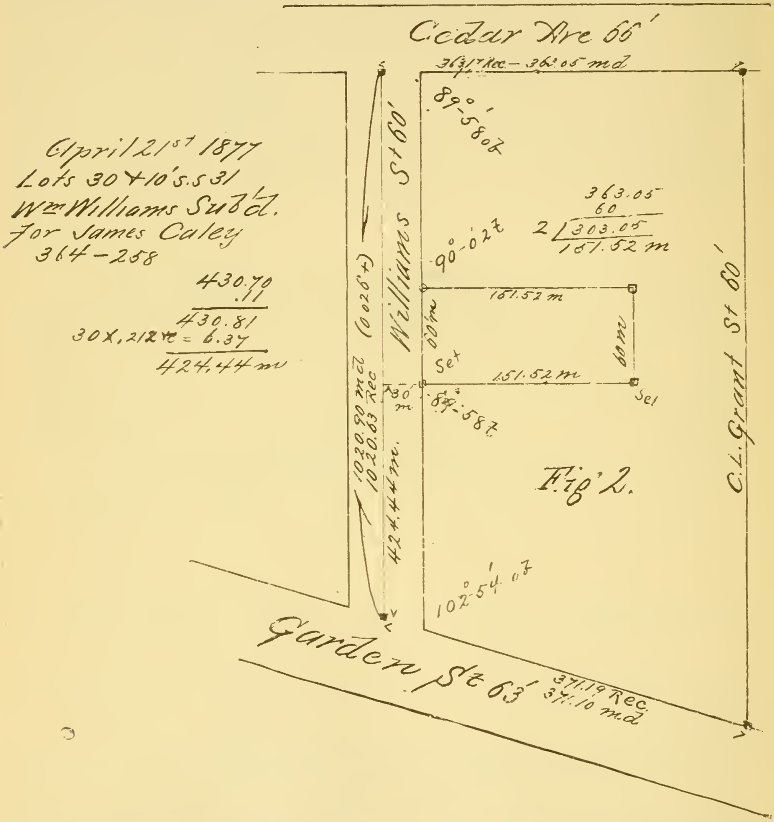
The tension of a steel tape or chain in measuring line should be constant, and for a 100-foot tape should never vary more than from 6 to 8 pounds.

April 9, 1880, S. J. Baker and J. S. Oviatt, members of this club, and the author made the following test with a 100-foot Chesterman steel tape on the City Hall base line with this result: At 3 pounds tension the tape was at its normal length; at 5 pounds tension, $\frac{1}{16}$ inch extension; at 10 pounds tension, $\frac{1}{8}$ inch extension; at 15 pounds tension, $\frac{3}{16}$ inch extension; at 20 pounds tension, $\frac{1}{4}$ inch extension.

The tape cross section was $\frac{3}{800}$ square inch area, which at 10,000 pounds per inch gives $37\frac{1}{2}$ pounds safe maximum strain. The formula for elongation gives $\frac{20 \times 100 \times 12}{29{,}000{,}000 \times \frac{3}{800}} = .22$ inch $= \frac{1}{4.5}$ inch, or nearly the same as the above test at 20 pounds tension.

To the end of checking off length fluctuations it is important that valuable city property be permanently fixed and determined within

the limits of 1,500 feet in every direction, and within less dimensions wherever practicable. And as a single measurement, though made in the correct direction, will not exactly locate a corner, great care should be exercised in determining its true location, and when so located, it should be fixed by a well-planted stone monument not less than two feet long. When stone monuments are thus set, the points are practically determined forever and become authority for the survey of adjoining property. And as it often happens that a monument known to be incorrect has had great bearing upon the beginning, making or ending of a survey,



it is important that the surveyor should carefully weigh all the evidence, and exercise his best judgment before deciding the location for fixed points. Consummate tact is required in the treatment of the old surveys. With them I have found my best expedient to be a careful large scale drawing. This will soon determine the truth of the survey, and if found true, such a drawing will greatly facilitate the labor of restoring points.

This city is one of the best monumented cities of the land, and for the care the Cleveland surveyor has exercised to determine and fix forever the true location of land corners, and therefore for the scarcity of disputed land lines, the people of Cuyahoga County may well thank him.

The best feature of the operation of surveying here is the completeness and simplicity of the surveyor's field-notes. It is the best of any thing in this line I have met. It tells of the fixed points he began with and of those he determined; it shows the distance he found, if measured between fixed points, and the distances he measured to locate others, whether the measured line was longer or shorter than its recorded length, and the rate per 100 feet of such increase or decrease. It also indicates his observed angle between fixed lines, or the angle turned off to locate a point or line. It is surprising in what small space, by abbreviations, he there tells the same story that by the old methods would require pages to relate. It saves space to the field-notes, and, what is vastly more to the surveyor, his time, and at a glance he sees the survey in detail.

Suppose, for illustration, we are to survey Lot 30 and 10 feet off south side of 31, William Williams subdivision, for James Caley, as per deed of Vol. 364, p. 258, County Deed Records. The field notes show that Williams street, upon which our property is located, is 60 feet wide, determined by stones at either side, that Grant street, next east, is likewise determined, what angle Cedar avenue and Garden street make with Williams; also the recorded and measured distances Grant and Williams streets are apart at either end; also those of the length of Williams street, its surplus per 100 feet; that as surveyed the north and south lot lines of the property were both made parallel to Cedar street, that it was located 424.44 feet from the stones in the centre of Williams street and on the north line of Garden street, and that the lot was staked off 60 feet wide and 151.52 feet deep, with stakes at the north corner, while stones were set at the south ones.

For distances: *Cal* is calculated; *md* that found between fixed points; *m* that measured to locate new ones. For angles: *ob* means it was found to be so much, while *t* means a given angle was turned off; *Set* the placing of new stones; *Rec.*, record, etc.

C. H. Burgess, member of this club, first introduced this system here, and he is undoubtedly its author, though the extreme modesty of that gentleman would not allow him to admit the fact. I would most heartily recommend this system of field notes to all surveyors, and that they adopt a uniform field note nomenclature. I would also respectfully recommend that the surveyors of the several States in their annual conventions adopt a uniform system.

No field note is complete that does not indicate all the mathematics used. Every calculation should be expressed. They may be so abbreviated that pages of figures can be shown in a very few lines.

The wealth of accumulated information possessed by the Cleveland surveyors is incalculable. In 1880 the State Legislature enacted a statute, whose enforcement has contributed largely to that of the people of this State. Previous to this time the surveys of the county surveyor, other than official ones, were his personal property, and when he passed from office his survey records went with him, and in removal from the county, which often happened, this information was completely lost. This was the cause of much annoyance and expense to the people of the county outside of the city. Now the county surveyor is compelled to

keep an official record of all his surveys and of all the methods and operations by which they were made. Within the city the lines are now pretty well determined, and therefore this official record has not the same force here as in the country.

But in the country fixed lines are scarce, and it is important that all surveys should be recorded in some one place of public record. More than this, I believe the county surveyor should, at public expense, keep an official list and record of all stone monuments, whether public or private, within the county, and when and by whom set, if possible. Recently, I was called into the country to make a survey, where I supposed there was not a stone monument for miles, nor could I find after careful search that there was any. Imagine my surprise when there to find no less than four, and all determining important lines of my survey. As near as possible the county surveyor's office should be the record of all land surveys within the county, but not so, however, to the detriment of private surveyors outside of that office. Every competent surveyor should have the legal right of taking testimony the same as the county surveyor now has.

The use of the decimal system was for years a distinguishing characteristic between the civil engineer and the surveyor. To-day you will find in some of the Newburg deeds something like this: 5 chains, 3 rods, 20 links, 4½ inches. Why yards and feet were not also introduced remains an unsolved problem. Certainly the array is a brilliant one, and the man who could master so much foreign language, with reason should have been deemed by his fellows very wise. But I doubt short of an elaborate calculation that any one, expert or otherwise, could tell you what all this meant, to say nothing of the source of errors such an unwieldly system was open or gave rise to. That its operation gave bad results will be answered by every city surveyor who has had the misfortune to labor there, that from the time this Newburg territory was added to the city until now, it was a leap into the dark to go there, and that too often, was it also true that a guess would get nearer the truth than a careful operation and fine calculation.

Complex systems are objectionable both for measurement, calculation, reduction and an intelligent understanding. They have no hold upon an intelligent and progressive people, and they are all fast becoming obsolete. The best system of lineal measurement is of the simplest notation, and of the most convenient standard.

That it has been used for all time and by all nations, both ancient and modern, and that the lengths should have almost universally been nearly the same, proves the foot to be the most convenient of all standards. For this reason it has become the practical standard of all English measurements. In many of the States the yard is the legal standard. Yet no one uses it, and it would be the same if the metre was legalized. Even in France to-day, we are given to understand that the common people use the old foot system. The people of this country are intelligent and ever ready to take up the new and useful, and if the metre was possessed of the great advantages claimed by its adherants, it would long since have been adopted. Both the yard and metre are open to the same objection as the inch—they are all inconvenient. The first are too large for small com-

parisons, and the last too small for large ones. It is, however, convenient to express all dimensions, either large or small, in feet and parts thereof—and these parts should be decimal parts, thereby rendering the standard the most convenient—the inch should be forever banished from common use.

By returning all his plats for record in feet and the decimals of a foot the Cleveland surveyor has done a great work in educating people to the use of the decimal one-foot system. Fifteen years ago, few could or would understand what one-tenth of a foot meant. Now, that they are compelled to use it, it is quite common to hear others than experts talk of feet and decimals. We have, therefore, eliminated a great source of error, and taken from the records the misunderstanding whether the dimensions are one thing or another. They are now all feet—not part feet, part inches, or part chains, rods or links, and I hope the time is not far away when we shall hear the last of feet and inches.

ORIGIN OF THE AMERICAN SYSTEM OF LAND SURVEYS.

JUSTICE TO THE MEMORY OF THOMAS HUTCHINS.

By Col. Chas. Whittlesey, Honorary Member of the Civil Engineers Club of Cleveland.

[Read June 24, 1884.

For more than thirty years I have neglected no proper opportunity to present what I conceive to be the historical truth, in regard to the author or inventor of the present mode of survey of the United States lands.

About ten years since, the Department of the Interior, in charge of those surveys, published a general resumé of their progress since 1786, when the new American method was first put in practice. In that document it is stated that the name of the author is unknown. At a meeting of the Ohio Institute of Geologists and Mining Engineers in 1883, the invention was attributed to Gen. W. H. Harrison.

In the Toledo *Science Monthly* for November, 1875, Professor Comegys, of Cincinnati, claimed it for Governor Edward Tiffin, the Third Surveyor General.

It has also been claimed for Prof. Jared Mansfield, the Second Surveyor General, 1803 to 1810.

In volume 2, number 10, issued in August, 1883, the Journal of the Association of Civil Engineers has an interesting and valuable article on the same subject, by Col. Moore, of the St. Louis Club. Without hesitation the credit of the invention is there given to Gen. Rufus Putnam, the first Surveyor General, 1796 to 1803. An abstract of this paper in the account of the proceedings of the Club, in the same number, contains what is necessary for my purpose in the following words : "Col. Moore's paper on the 'Origin of the Present System of U. S. Land Surveys' was then read. After giving a graphic account of the endless confusion arising from the old system he very clearly proved that Gen. Rufus Putnam, of Massachusetts, was the author of our present system of sections, towns and ranges. This system was first employed in the eastern part of Ohio (then the Northwest Territory) in 1786, and has since been exclusively used in all government land surveys. The writer thought a

monument should be erected to the man whose genius has thus saved millions of dollars to the landowners of the Northern and Western States that otherwise might have been spent in litigation. The paper is a genuine contribution to the history of this subject, as the facts were obtained from some musty old records now in the possession of the Marietta College, of Marietta, Ohio. A vote of thanks was tendered Col. Moore for his valuable paper."

I became convinced long since that the plan had its origin, in an incipient state, but in substance the basis of the present system, in 1764, with Captain Thomas Hutchins, who was of the Royal American or 60th Regiment of Foot. In none of the claims or the discussions referred to, does the name of Hutchins appear. If I am right, none of the claimants were born when he conceived of the plan, and which twenty years later he was the first to put in practice. Hutchins was one of the remarkable men of revolutionary times, a surveyor, engineer and scientist, worthy of an association with such as Franklin, Rittenhouse, Ellicott and Fitch. The most remarkable feature of his history is the fact that his name is still under a shadow so dense that it does not seem to be known to modern investigators. The authors of many other important discoveries have been equally unfortunate. Before they are appreciated even by philosophers, they have passed away from earth, in this case for nearly a century. No one has a greater reverence for Rufus Putnam than myself. He was one of the great characters of a time when conspicuous men were numerous. His merits were far beyond the promotion he received. Washington gave to him an unwavering confidence, as a patriot, a military officer and an engineer.

At the close of the war Putnam took an active part in the scheme for Western emigration by the officers and soldiers of the war. Mentally and morally he has left the impress of his exalted character to this day. But it cannot be successfully claimed that he discovered or invented our splendid system of land surveys as outlined in the Act of Congress, May 20, 1785. The work under this act was to be executed by the Geographer of the United States, an office then filled by Thomas Hutchins. He had for assistant surveyors one deputy from each State. Rufus Putnam was the surveyor for Massachusetts, but, being occupied in the Province of Maine, John Matthews took his place on the Ohio survey, usually known as that of the "Seven Ranges." I find nothing to show that Putnam was on the Ohio before the spring of 1788. Under the act of May 18, 1796, he was appointed by Washington to be the First Surveyor-General.

In July, 1786, Hutchins commenced in person to run the base line of the "Seven Ranges," starting at the north bank of the Ohio River. where it is crossed by the west line of Pennsylvania. Every six miles as he proceeded to the west, deputy surveyors started south with their range lines to the Ohio.

This brings us to the question of priority. Whoever reads the account of Col. Henry Bouquet's march from Philadelphia to Fort Pitt, in 1763. and thence in October, 1764, by the way of the Little Beaver, the Big Sandy, and the Valley of Sugar Creek, to the Forks of the Muskingum at Coshocton, will find in the appendix a plan for a system of forts and settlements in the Indian country. This book was published at Philadel-

phia with maps and illustrations in 1765, and reprinted at London by the geographer to the crown. A French edition was issued soon afterward. It has been reprinted in fac simile, by Robert Clarke, of Cincinnati, in 1868. The title is very full, and informs us of many things, except the most essential one, the name of the person who composed the account. Why there should have been so much mystery in regard to its authorship is by no means obvious. At the foot of the title page the public is informed that the work was "Published by a Lover of his Country." Until 1850 literary and historical persons in the United States ascribed the substantial parts to Hutchins, who was assistant military engineer to the expedition. About that time the late Peter Force, of Washington City, discovered a letter from the Rev. Wm. Smith, to Sir William Johnson, dated January 13, 1766, in which he states that he intended to send a copy of "Bouquet's Expedition, which I drew up from some papers he favored me with." Mr. Smith was not in the expedition. Most of the documents show by internal evidence that they were written by officers or persons who were of the command, and spoke from observation. The field of the engagement at Bushy Run in August, 1763, was surveyed and the plan signed by Hutchins. The description is evidently by an eye-witness, giving minute details of the engagement. Col. Bouquet, the commanders was fully capable of writing it, but would not have referred to himself in a manner so complimentary. The march from Pittsburgh the year following was surveyed day by day and plotted by Hutchins. Captain Brehm was engineer to the 60th Regiment, but it does not appear that he was present. "The Royal Americans or the 60th Regiment of Foot." was composed of three battalions, with a colonel and three lieutenant-colonels. If it were shown that Brehm was with the command, some of the documents might be properly attributed to him.

There are known to have been a number of books and papers that were written and published by Captain Hutchins. A topographical description of "Virginia, Pennsylvania, Maryland and North Carolina" was printed at London in 1778. About this time he was arrested for communicating with Benjamin Franklin at Paris. His fortune, amounting to $60,000, was confiscated. He managed to escape from England, and reaching the United States at Savannah, Ga., was appointed Geographer General to the United States. The transactions of the Philadelphia and of the American Philosophical societies for 1775, 1776 and 1783 have papers written by him. It is probable, judging from the style of the articles in the *Gentleman's Magazine* for 1763, relating to Bouquet's march, that they were also of his composition. In 1784 he published at Philadelphia a topographical description of "Florida and Louisiana." illustrated by maps. In the preface to the work on "Virginia, Pennsylvania, Maryland and North Carolina," he says: "Those parts of the country lying westward of the Alleghany Mountains, on the rivers Ohio and Mississippi and other rivers and lakes here described, were drawn from my own surveys, made in several campaigns between 1764 and 1775, as assistant engineer to Captain Brehm, of the 60th or Royal American Regiment." In 1784 he was one of the commissioners to run the west line of Pennsylvania on a fixed meridian of longitude, where it is now. His literary and scientific

attainments were such that of all the prominent characters of that time, none was better qualified to write the material points of the account of Bouquet's expedition, which was merely edited by Smith. Of this work the appendix is of nearly as much importance as the historical parts. The editor states that it was written by an officer in the British Service "of great ability and long experience" in the Indian contests west of the Alleghanies. It gives a general plan and all the details for defense of the western frontiers, by a series of forts and military settlements. Its authorship lies between Col. Bouquet and Capt. Hutchins with the probabilities in favor of the latter. So much of the plan as related to the survey of lands may be found on pages 119 to 121 as follows: "Lay out upon a river or creek if it can be found conveniently a square of 1,760 yards or a mile on each side, which will contain 640 acres." Accompanying the general description of the forts and stockades, is a plan and many details which it is not necessary to repeat, except as to the survey. "Around the town (stockade fort) are the commons of three miles square, containing exclusive of the lots above mentioned 5,128 acres. On three sides of the town five (5) other squares will be laid out, of three (3) square miles, containing 5,760 acres each." (Page 120.) The entire tract for each fort forms a township six miles wide and nine miles in length. All the sub-divisions are to be squares and all the lines parallel. *This is the first announcement of an allotment in squares of a mile on each side*, the rudiments of the plan put in operation and carried out by the United States since 1785.

The petition to Congress of June, 1783, and Gen. Putnam's letter to Gen. Washington, on the same subject, embody many ideas distinctly set forth in this appendix, published in 1765. Geographer Hutchins was about eight years the senior of Putnam. Both were surveyors and engineers, and it is not improbable were personally acquainted during the war. Putnam must have seen and read the account of Bouquet's march, issued ten years before the revolution. The suggestion as to an improved mode of survey would be fully appreciated by him. What pertains to Indian warfare west of the mountains would also make a deep impression upon such a mind. The suggestions of his letter to Washington contemplated townships not less than six miles square nor more than six by twelve miles. In this as in the plan of 1764 the lines were not necessarily north and south and east and west. In both plans, however, this might be inferred.

The Hon. H. J. Coolidge, Secretary of State for Massachusetts, informs me that in 1781 a legislative committee was raised to consider the disposal of unappropriated lands in Maine, and that on the 11th of July, 1783, the County of York was directed to be surveyed in townships of six miles square. In other counties prior to 1794 there were laid out towns and ranges of that size, but the lines were not on meridians and parallels. As it now appears, the act of Congress of May, 1785, is the first instance where this was made imperative. The value of such a system was so apparent that it was generally accepted by the States. In 1786 the State of Connecticut directed the Western Reserve to be surveyed in towns and ranges of six miles square, following the meridian. However, no surveys were made in the field under this resolution by the

State of Connecticut. Massachusetts had lands in Western New York, which were sold about this time and laid out in the same manner as the government lands. Gen. Putnam was unquestionably an advocate of the system in 1783. His influence with Congress was, no doubt, exerted in the same direction. But I think it must be admitted that Geographer Hutchins, as an officer of the Government, charged with the subject under discussion, and present at the seat of government, was consulted in the act of 1785, and had more influence over its provisions than any other person. If he was the author of the plan of 1764, it must have been a favorite project with him, and which he was about to realize after many years' reflection. It would have been in that case the study of twenty years, brought at last to such perfection, that for simplicity, clearness and economy, it has not yet been superseded. With improvements gradually introduced, it covers all the States and Territories of this union organized since the revolution. Col. Moore very justly remarks that "The memory of the founder of this system, which has proved such a benefit to our country, is worthy of a monument," and also its "beauty, simplicity and accuracy are not appreciated even in the West, where no other system is known. No other country possesses one so nearly perfect, both in theory and practice." In the present state of information it is not directly demonstrable that Thomas Hutchins was the original designer of the system, but it is a fair presumption.

While record proof is wanting, no other officer or person is known that has a positive claim to the authorship of the appendix written in 1764. The proof is direct and positive that he was the first person to put the system into operation in the field in the year 1786. He continued the work in the "Seven Ranges" in 1787 and 1788 in person, under the act of 1785. After more than thirty years of active life as an officer, explorer, surveyor and engineer on the frontier he died in the service of the government, at Pittsburgh, in April, 1789, nearly sixty years of age. His genius and services are, like those of his compatriot, John Fitch, the inventor of the steamboat, unknown to the present generation. It does not appear that he was married. If there were relations at his birthplace, in Monmouth, New Jersey, no effort was made by them to sustain his memory and reputation.

Isaac Craig, Esq., of Allegheny City, Pa., writes me that many years since the First Presbyterian Church of Pittsburgh, under the persistent lead of an iconoclastic pastor, applied to the Legislature for power to vacate part of its cemetery. It was opposed by the old citizens, who venerated the graves of their pioneer fathers and heroes as sacred ground. But the bill finally passed. The correspondent of a Pittsburgh paper speaks of its desecration in these terms: "I wandered yesterday to the grand old churchyard of the First Presbyterian Church and Trinity Episcopal Church, the only one left in the city. * * * Here lie the remains of the pioneers of Western Pennsylvania, the men whose brave arms assisted Washington in achieving our national independence. Few churchyards in the West can boast of greater antiquity, or claim to be the resting place of so many historical characters. The sight that met my eyes rudely scattered its charms. Men were at work digging up the remains. * * * I asked a cartman where he was taking those sacred ashes, 'Bedad, them's

no ashes. but dead men's bones; we take them to grade the exposition grounds.'" It appears that this was done to make room for an addition to the church for a Sunday-school. How can such persons expect to have their own remains respected? There was a stone and an inscription in the following terms:

In Memory of
THOMAS HUTCHINS,
Geographer of the United States,
who departed this life April 29th, 1789.

Hutchins was born about the year 1730, two years before Washington. He was commissioned an ensign in the British service before he was of age, promoted to a lieutenancy December 18, 1757, and in June, 1758, made quartermaster in Col. Mercer's battalion.

His promotion to a captaincy and assistant engineer, must have occurred before 1763.

FOUNDATIONS OF THE STONE ARCHES OF THE SUPERIOR STREET VIADUCT AT CLEVELAND, O.

By B. F. Morse, Vice-President of the Civil Engineers' Club of Cleveland.

[Read April 8, 1884.]

Thinking that something about the Superior Street Viaduct would or could be made interesting to the club, I beg permission to present the following, in reference to the settlement that has taken place in the foundations of the masonry of the arches on the west side of the river.

I have found from observation that it is very seldom that massive or heavy masonry like that of the viaduct can be found but what has more or less cracks or fractures, caused from imperfect foundations or unequal settlement.

It is now over four years since the viaduct was completed and opened for public travel. The part of the viaduct which shows the greatest settlement, referred to above, consists of eight arches of eighty-three feet span, and two, ninety-seven and one-half feet span, with two retaining walls 256 feet long, averaging fifty feet in height. The arches have a rise of thirty-three feet above the spring line, and the whole length of the masonry is 1,356 feet, and is sixty-four feet wide; its greatest height from the top of the coping to the bottom of the footing courses of piers is 74½ feet. The grade of the coping and spring line of arches rises six inches per 100 feet from the end of the iron draw to the west end of the masonry, beyond the N. Y., P. & O. Ry.

There are 53,575 perches of masonry of 25 cubic feet each in the foundations and superstructure of the first nine arches, from the river west; and there are 242,767 lineal feet of piles driven under the foundations of the nine arches, or something over forty-five miles in length of piles. These piles are from 30 to 45 feet long, and were driven in rows from two to three feet apart from centres. The material into which they were driven is what is called Erie clay, a dry, compact, blue quicksand, varying in density to a considerable extent. That is, there were some strata that were hard and some soft, even in the same foundation. The piles were cut off below the surface of the water in the lake, and the material

in and around the heads of the piles was excavated or removed to a depth of one foot below the top of the piles and the space filled in solid with concrete, which was leveled off with top of piles; then oak timbers 10 x 12 inches square were laid on top of the rows of piles, leaving a space of about one foot between the timbers. These spaces were then filled in solid with concrete and leveled off with top of timbers. Then a grillage of 10 x 12-inch square oak timber, laid close together, was laid crosswise on or over the entire surface; on this grillage the masonry was built.

The greatest care was taken by the engineer in charge—Mr. S. H. Miller—to drive the piles and prepare the foundation so that the settlement, if any, would be uniform, and to his constant supervision and great skill in driving piles according to the best known formula, do I attribute the satisfactory results obtained. In some parts of the foundations the piles were driven so close together that no more could be driven without displacing those already in place.

The entire weight resting on the ten-pile foundation is estimaied to be 121,240 tons. The weight on some of the piles being as much as twenty tons, and the weight per square foot of surface covered by the foundations exceeds, in places, five tons. While the weight per square foot on the foundations of the iron viaduct east of the river is only about one and one-half tons. The piers and abutments west of the river, commencing at west end of iron draw—with No. 8, are numbered consecutively, up to 17—that being the abutment at the west end of the 9th arch.

Test levels were taken on the footing courses of all these piers and abutments before and after they were built, up to the spring line of arches, at intervals of from 6 to 12 months, until the viaduct was completed, the roadway paved and the full or permanent load was placed upon the foundations, and yearly up to the present time. The viaduct was completed and opened for public use December, 1879. The first test levels were taken November, 1875. A period of about four years elapsed while this part of the structure was being built, or while the load was being placed upon the foundations, and the settlement that took place during the four years, as shown by test levels, is 2½ inches at pier No. 8, 3 inches at No. 10, 3½ inches at No. 11, 3½ inches at No. 12, 2¾ inches at No. 13, 3½ inches at No. 14, 5 inches at No. 15, 4¼ inches at No. 16 and 5 inches at No. 17—showing a settlement in the foundations of from 2½ inches at pier 8, to 5 inches at No. 17, during the four years it was being built. Since the completion of the viaduct, and all the permanent load was placed upon the foundations, up to the present time, but a very small amount of settlement has taken place, only about ½ to ⅝ of an inch during the four years since it was completed.

The most remarkable thing is, that all this settlement should have taken place so uniformly from east to west or from west to east. If it had not settled uniformly, the masonry would probably ere this have shown some ugly cracks. As it now is, the settlement of the north end of piers 14 and 15, about one-tenth of a foot more than the south ends, or the unequal settlement of these two piers, has caused the three arches adjacent thereto, to crack longitudinally, nearly through the centres of them. These fractures are light and will do no damage to the structure.

I am well satisfied that these foundations are now loaded with all they can safely carry, and now, while I am on this subject of foundations, I will say, that, having never heard any discussion upon the matter as to how much per square foot generally the material on which the city is built will safely carry, there must necessarily be a difference according to location. Structures located on the river flats, where there is no sand or gravel, underlaid with springs and quicksand, will carry I think, a greater load than the materials upon the table land. But as most of our large buildings are located upon the table land, from 70 to 100 feet above the lake, on sand and gravel, underlaid with quicksand and water, it is a very important matter to know how much base to give the foundations to prevent undue settlement.

So far, ordinary buildings 4 to 5 stories high, with the footings from 3 to 4 feet in width, averaging 1½ tons to the square foot, will not settle very much, but as the city grows, and heavy and higher buildings are constructed, it becomes a matter of very great importance to capitalists investing their money in expensive and elaborate buildings, to have them so built that they will not become unsightly or unsafe by the unequal settlement, or from too narrow foundations. Will some of our architectural members enlighten us on this subject?

AN ALIGNING INSTRUMENT.

By H. F. Dunham, Member of the Civil Engineers' Club of Cleveland.

[Read July 8, 1884.]

It was my purpose to have the brief paper to which I draw your attention come up at the meeting devoted to railway interests, and then I only thought of occupying a few minutes after the regular papers for the evening had been read and discussed. In fact I had some misgivings about presenting a paper upon a subject so restricted or one in which but few of our members would be really interested, and another thought also has a bearing, and I do not know but it is the more important. The instrument referred to may find its way to the trade, and I would not like to be understood as introducing matter to our club, and especially to the columns of our valuable journal, which might appear to any one to have been presented for the mere sake of publicity—of bringing it to the attention of those who might some time become purchasers.

So far as the Journal is concerned I have no fears, for all our papers go before an able committee upon publication, and they cannot do me a greater favor than to return this if it seems to them to be unworthy. And I want to say to the members of the club, that if a subject which interested me by its novelty has not the merit required to interest you, neither does it possess sufficient magnitude to tire you severely, nor for a very long period.

Some two years ago in a letter to the *Engineering News*, I mentioned the fact that our common hand or Locke level was a larger and more clumsy instrument than it needed to be. As nearly every one is familiar with the instrument, it is hardly necessary to describe it at length. There is a bubble, a cross-line, a prism and a tube. A ray of light passes downward through the bubble, is turned at right angles by the prism and

appears to reach the eye from a horizontal direction only, causing the level tube to assume a vertical position and the bubble to appear to move up or down as the forward end of the instrument is elevated or lowered. The prism occupies a place upon one side of the main tube or barrel which is made large enough to enable the observer to see, through it, a field of considerable breadth and by aid of the cross line to fix the position of a horizontal line that is level with the eye. Although the field of the instrument as now constructed is quite large, it often happens where there is no well defined object in front of the observer that he experiences some trouble in fixing or recalling the exact position of the level line after the instrument has been removed from the eye, and this difficulty is increased when there are trees or shrubbery or smooth fields in the foreground.

Obviously it would be better if the cross line could remain in position to catch the eye after the instrument had been taken away. Then the observer would have an unobstructed view and could note the position of all the objects in front of him, with reference to the level line.

Now this result can be obtained very easily and simply by putting an opaque disk in the place of the glass at the front of the level, to shut out unnecessary light, and then using the instrument with both eyes open. When this is done, it will be found that the covered end of the instrument appears to be transparent, and the cross line seems to be projected across the field, and its position with reference to the bubble can be studied and adjusted, and at the same time the unaided eye may also note its position and the relation of the level line to the objects in the foreground.

In this description of a change in the hand level I have purposely been particular as to details, that you might see by what easy steps I was led to make and associate with the level a smaller, independent, but mutually helpful instrument.

These were the facts : An opaque object seemed to be transparent, and a ray of light coming from a vertical direction, and seen by only one eye, appeared to and practically did coincide with another ray coming from a horizontal direction, and seen only by the other eye. Now it will readily appear that by reversing this method and ignoring the level tube and bubble, we should be able, with only the barrel of the instrument and the prism, to fix the direction of a ray of light that should be perpendicular to any other ray of light that might come to the observer from any object. For it would only be necessary to look at the selected object with one eye and simultaneously with the other at the prism, held, of course, in the same direction, and whatever object was seen through the prism and behind the cross line to cover the first object, would be in a line perpendicular to the line first established within small limits, and at the point in that line which was occupied by the instrument, or practically at the point of observation.

This of course assumes the use of a right-angled prism and one truly ground.

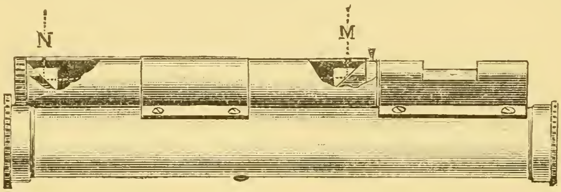
Knowing that an angle of 90° could be determined in this simple manner, the question of what other angle might be so determined, and what one would be of most service naturally came up.

A locating engineer was never long in charge of a party without having made himself hoarse by shouting to his transit-man, or other assistant, that he wanted to be and must be lined in toward some object about which he had vociferated all the particulars, but concerning which no other member of his party had the least knowledge. The difficulty, too, of getting into line between two points when no transit or assistant is at hand is often noted.

The question also of what lies behind when facing in a given direction is important, and many are the expedients resorted to for finding out. One method involves the use of a stick, usually more or less curved, one end of which is carefully directed toward an object, and then the observer quickly puts his head "about face" in the hope that he may discover what object lies in the direction of the other end before his instrument gets off its centre.

Another method involves making a little path in the snow or upon the ground leading toward the object known to be on line, and then by turning about the engineer can determine the direction from whence the path came.

The text-books illustrate a method where there is a possible hill in the way by which two men can determine a line, each one moving the



other and himself, according to directions carefully laid down. The method of getting into line when one has a transit is well known.

Such considerations and the difficulties often experienced in the field, led me to fix upon an angle of 180° in addition to the right angle as the one most to be desired.

To accomplish this I put two right-angled prisms into a case, which becomes a part of the hand level, or is more convenient in that form than in any other, with suitable openings, and so adjusted them to each other that a ray of light falling upon one prism would be deflected to the second, and from that out of the instrument in a line parallel with its first direction. The length of the case was not important, only that it should exceed the distance from the centre of the eye to the outside of the ear in the genus Homo.

The method of using is very simple. The instrument is held in a horizontal position, one eye being directed to the small opening and the other looking naturally at any object in the established line, or the line to be extended. Two objects will be seen, both appearing to be in the same direction—that is, in front of the observer—and it will be difficult to say by which eye either object is seen, or that each is not seen by both eyes—save for the fact that the person using the instrument is aware of its position.

The nearer of the two objects will appear to be transparent, and through it the other may be seen, and the important fact to be noted is this:

That object or portion of an object seen by one eye which covers an object seen simultaneously by the other eye lies substantially in a straight line extended from the second object through the point occupied by the observer.

In other words, the observer is in line between any two points that appear to coincide when viewed simultaneously, one through the instrument and the other with the naked eye. The advantages of such an instrument are apparent. With the locating engineer it takes the place of the assistant and the stick, and the path and the transit, and in two respects it is better than the latter for his purpose, besides being more convenient.

Its use requires but a fraction of the time necessary to level an instrument, and by holding it in a vertical position a grade line, or a line in a vertical plane, can be projected, something that could not readily be done with a transit, unless it was provided with a vertical circle. By this use of the instrument the slope of the country passed over can be compared with that still in front. In working along a slope where it is necessary to know the elevation of points in advance that are on line, by the aid of the aligning instrument one can tell where the points are, and by the aid of the hand level he can ascertain their relative elevation.

The instrument is not intended for accurate work, but studied theoretically it has some peculiar features and is not in all respects like other instruments of precision. (?)

If in reversing a transit the error amounts to a inches in 100 feet, the error in 10,000 feet will be 100 times a inches, or if $\frac{a}{100}$ equals the angular error in 100 feet, the angular measurement of the error in 10,000 feet would still be $\frac{a}{100}$. But with this instrument, if the measured error in 100 feet were a inches, the measured error in 10,000 feet would only be a inches. And if the angular measurement of the error for 100 feet be $\frac{a}{100}$, the angular measurement of the error for a distance of 10,000 feet would be $\frac{a}{10,000}$. The longer the distance the more accurate it becomes. This of course assumes that the instrument is in adjustment, its only theoretical error being due to its length and the distance between the eyes of the observer, and this practically is of no importance in the preliminary work for which the instrument is designed. And if necessary to correct for this error, it can be done by simply using the instrument at the other eye.

It has but few parts. There should be no trouble with its cross lines, for it has none. It should never be out of focus, for it has no focus. Its line of collimation is a straight line. It is a tangent instrument, but it has no tangent screw.

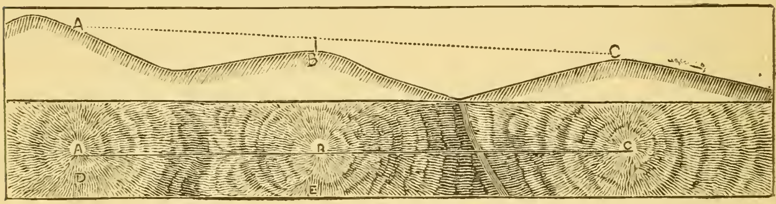
It is the only instrument with which I am acquainted that does not depend for its accuracy upon care in using and holding.

No haste or carelessness, save actual abuse and injury, can make this instrument indicate that three objects are in line when they are not substantially in line.

Encouraged by another member of the Club, I have made an examination for eccentricity. My opinion is that it has none. And I think this is confirmed by the laws of vision which are so permanent and universal that the most eccentric man cannot examine closely two different objects at the same time.

But here I find that I must proceed carefully. I should be obliged to admit that if a person could so control his organs of sight as to use them independently and look at two objects at once, my instrument would be inaccurate and worthless for him. Yet I have shown you that any one can (with the instrument) see widely separated objects at the same moment.

Therefore—But let us be practical rather than too logical.



ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

MAY 21, 1884:—A regular meeting of the Boston Society of Civil Engineers was held at 7:40 P. M., President G. L. Vose in the chair, twenty-six members and two visitors present.

Mr. Desmond Fitzgerald read a paper on the subject "Does the Wind Cause the Diminished Amount of Rain Collected in Elevated Gauges." Discussion followed by Messrs Brooks, Philbrick, Bradley, Vose, Rice, G. S. Freeman, Stearns and Hale.

Mr. F. P. Stearns read a paper on "Tunnel Alignment Based on Dorchester Bay Tunnel." Discussion followed by Messrs. Brooks, Philbrick, Fitzgerald, L. F. Rice, G. S. Rice

The record of the last meeting was read and approved.

Mr. Josef Colver Turk was proposed for membership, recommended by Messrs. G. L. Vose and H. L. Eaton.

Messrs. Charles W. Raymond, Henry F. Walling and James W. Johnson were elected members of the Society.

The Treasurer, Henry Manley, asked the Society for an interpretation of Article XVI. of the Constitution, and announced that it had been his custom to require a payment of $3 from non-residents at or before the annual meeting, and if payment was not made at that time to require the full assessment. The justice of this practice has been questioned by some non-residents, who claim that having once notified the Secretary, they ought thereafter to be considered non-residents and be allowed such time for payment as is provided by Articles XVII. and XVIII. of the Constitution and By-Law 5.

On motion of Mr. E. W. Howe it was voted: That the matter be referred to the Government for suggestions.

The Treasurer announced that the cash in the treasury was in excess of its needs and suggested that a portion of the same be invested.

On motion of Mr. E. P. Adams it was voted: That the question of investment be referred to Government with full powers.

On motion of Mr. F. P. Stearns it was voted: That the Government be requested to appoint a committee to arrange a programme for the meetings of the Society.

[*Adjourned.*] H. L. EATON, Secretary.

JUNE 18, 1884:—A regular meeting of the Boston Society of Civil Engineers was held at 8 P. M., President George L. Vose in the chair, fourteen members nd two visitors present.

The record of the last meeting was read and approved.

On the subject of non-resident dues, which was referred to the Government at the meeting of May 24, the following recommendations were made:

"The Government recommends to the Society that the Treasurer be authorized to receive $3 from all members who have heretofore notified the Secretary of their desire to avail themselves of the modified assessment provided for in Article XVI. of the Constitution.

"The Government further recommends that the Constitution be so amended

as to prevent the possibility of any misunderstanding of its meaning relative to the matter of dues and assessments, and that a committee be appointed to formulate such amendments.

"That in view of the uncertain condition of the market, it would be inexpedient to make any investment, and that it be postponed until some more favorable time."

On motion it was voted: That the recommendation of the Government interpreting Article XVI. of the Constitution be adopted, and the Treasurer be authorized to act in accordance therewith.

On motion it was voted: That a committee of three be appointed by the President, to consider the matter of the amendments to the Constitution relating to dues, and report to the next meeting.

During the afternoon previous to this meeting, the Society, by invitation, visited the new building of the Massachusetts Institute of Technology, and were conducted through the several departments by Professors G. L. Vose and S. H. Woodbridge. The system of heating and ventilating adopted was described by Professor Woodbridge in a very clear and interesting lecture.

Mr. Abert F. Noyes read a paper on "The Heating and Ventilating of School Buildings."

Professor Woodbridge continued his lecture on his system of heating and ventilation.

President Vose described and exhibited several plans of the C. P. R. R. Ferry at the Straits of Carquinez, between Benecia and Port Costa, California.

Mr. D. Fitzgerald gave a description of the Eads Ship Railway at the Isthmus of Tehauntepec, with a synopsis of some of the papers read at the recent convention of the American Society of Civil Engineers at Buffalo.

On motion it was voted: That the July and August meetings be omitted.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

JUNE 18, 1884:—223d meeting; 32 members present. The Secretary being absent, Mr. C. W. Melcher was appointed Secretary pro tem by the Chair. Minutes of previous meeting read and approved.

The following gentlemen were unanimously elected to membership: E. C. Jewett, A. N. Smith and A. L. Sieghortner. The name of Mr. E. C. Goldstein, proposed by Anthony Blaisdell and E. D. Meier, was laid over till next meeting on account of the absence of both his sponsors.

Mr. J. D. Sanders was proposed for membership by J. B. Johnson and H. A. Wheeler.

Mr. C. E. Jones read a few notes left by the chairman of the Committee on Smoke Prevention.

Mr. Taussig suggested that the committee investigate the furnace at the works of the Shickle, Harrison & Howard Iron Co.

Mr. Holman mentioned the furnaces at the station of the Cable R. R. Co., Chicago, as using manure and slack for fuel, and Mr. Pond spoke of a furnace employing manure alone.

Mr. Jones said that the Williams furnace at the University did not give as good evaporation as their regular furnace.

Mr. Woodward said that the Murphy furnace at the court-house did not give very satisfactory results.

Mr. Potter said imperfect combustion due to the formation of carbonic oxide was very injurious. That a furnace may lose over one-half its useful effect and still no smoke be visible. Thought the educated stoker the best means of smoke prevention.

Mr. Pond said that in England the fireman was fined if smoke was seen issuing from the chimney.

Moved that the Committee on Smoke Prevention be continued and instructed to report.

Moved that when the Society adjourns it adjourns to meet the second Wednesday of November.

Mr. Constable made a few remarks on the "Bower-Barff Process of Rustless Iron."

[*Adjourned.*] CHARLES W. MELCHER, Secretary pro tem.

WESTERN SOCIETY OF ENGINEERS.

AUGUST 5, 1884:—The 191st meeting was held in the Society rooms, at four P. M., President Cregier in the chair.

In the absence of the Secretary, Mr. G. A. M. Liljencrantz was appointed Secretary pro tem.

The minutes of the preceding meeting were read and approved.

Mr. William Overton Winston, contractor, of Minneapolis, Minn., was proposed for membership.

The President being called away, Vice-President Randolph took the chair.

The Committee on Revision of Constitution and By-Laws made an informal report, which was discussed by the members present. The Committee then asked for further time, which was granted.

[*Adjourned.*] G. A. M. LILJENCRANTZ, Secretary pro tem.

AUGUST 19, 1884:—The 192d meeting was held on Tuesday, at four P. M., President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Upon ballot, Mr. John Allison Porter was elected a member.

The Secretary announced the reception of a photograph-likeness from Mr Albert F. Robinson.

Mr. Liljencrantz, for the Committee on Revision of Constitution and By-Laws, reported progress, and presented several amendments for consideration. These were discussed separately, and the matter was referred back to the Committee.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

SEPTEMBER 2, 1884:—The 193d meeting was held at 4 P. M., Vice-President Randolph in the chair.

The minutes of the preceding meeting was read and approved.

Mr. John Saltar, Jr., Western Manager for Schleicher, Schumm & Co., residing in Chicago, made application to be admitted as a member, indorsed by Messrs. Powell, Liljencrantz and Wright.

Mr. William Overton Winston, proposed at the 191st meeting, was elected a member.

Mr. John Zellweger read a paper, "Gaseous Fuel, No. 1, Gas-Producing Plant."

Mr. Wright presented a paper, "Street Railway Joints."

It was voted that these two papers should be printed.

Mr. Liljencrantz, for the Committee on Revision, presented several amendments to the Constitution and By-Laws. After discussion the report was referred back to the committee.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

June 24, 1884:—Special meeting held, President Holloway in the chair. Minutes of last meeting read and approved.

The Commitee appointed at the last meeting on Amendments to the Constitution reported the following amendment to Art. IV :

Section 1. Civil, Mechanical and Mining Engineers, Geologists, Architects, Astronomers, Analytical Chemists, or other persons engaged in scientific pursuits pertaining to some one of the above professions, shall be eligible to membership.

Section 2. There shall be four classes of members, Active, Associate, Corresponding and Honorary. *Active Members* shall consist of members who are, or have been, engaged as Civil, Mechanical and Mining Engineers, Architects, Astronomers, Geologists or Analytical Chemists. *Associate Members* shall consist of such other persons, whom the Club desires to elect, as are engaged in scientific or other pursuits pertaining to some one of the professions abovenamed.

Mr. J. L. Cully read a paper entitled "The Cleveland Surveyor."

The President read a paper written by Col. Chas. Whittlesey, entitled "Origin of the American System of Land Surveys."

The following resolution was adopted :

Resolved, That the Chair appoint a committee of five on Reception and Introduction.

[*Adjourned.*] M. W. Kingsley, Rec. Sec'y.

July 8, 1884 :—Regular meeting held, Pres. Holloway in the chair. Minutes of last meeting read and approved.

Mr. L. H. Clark, Chief Engineer of the L. S. &. M. S. Ry., was elected an active member of the Club.

The committee appointed to extend the courtesies of the Club to the Institute of Mining Engineers which met in Cleveland June 25, reported that the managers of the N. Y., P. & O. R. R. had kindly placed a train at the disposal of the visitors, and that they had been invited to make use of our club-room and had been shown other courtesies. A vote of thanks was tendered the railroad managers for the use of the train.

On motion of Mr. Bowler the Treasurer was instructed to pay $10 toward defraying the expenses of the Committee.

On motion, the following resolution was unanimously adopted :

Whereas, It is learned with much regret that the Western Society of Engineers contemplates withdrawing from the Association of Engineering Societies; Therefore.

Resolved, That a committee of three be appointed, of whom the Chairman shall be one, to prepare and present a series of resolutions embodying the sense of the Club in reference to the matter. The committee consisted of J. F. Holloway, Charles Latimer and M. E. Rawson.

Mr. H. F. Dunham read a paper entitled "An Aligning Instrument." Prof. Robinson, of the (Ohio) State University, was present and took part in the discussion of the paper.

The amendments to the Constitution as proposed at the meeting of June 24 were unanimously adopted.

Mr. Rawson proposed the following amendments to the By-Laws, to conform to the Constitution as amended.

ARTICLE III.—ELECTION OF MEMBERS.

Section 1.—All nominations for Active, Associate and Corresponding Members shall be preceded by an application in writing, signed by the nominee, stating his

occupation and professional experience, which shall be indorsed by two Active Members of the Club, to whom he must be personally known.

Section 3.—Election of members shall be by ballot at any regular meeting subsequent to that at which the nominations are made. Active, Associate and Corresponding Members must receive nine-tenths of all the votes cast to be elected, and no person rejected shall be eligible for nomination for one year. In case of Honorary Members, an unanimous vote is required to elect ; in case of non-election, no record shall be made.

Section 4.—No person shall become an Active, Associate or Corresponding Member unless he shall have signed an agreement to abide by the Constitution and By-Laws, and has paid his initiation fees within thirty days after notification of his election.

Section 5.—Corresponding, Associate and Honorary Members shall be entitled to all the privileges of Active Members except the right to vote and hold office.

ARTICLE IV.—DEPRIVATION OF MEMBERSHIP.

Section 3.—A member may be expelled for cause deemed sufficient by the Club, by a two-thirds vote of the Active Members present at any meeting, providing such Member shall have two weeks' notice of the charges preferred against him and of the time appointed for their consideration.

ARTCLE XIV.—DUES AND FEES.

Active and Associate Members shall pay an initiation fee of five dollars and an annual dues of six dollars, payable annually, in advance, on the 1st day of March of each year. This shall include the subscription to Case library. Corresponding Members shall pay one-half the fees and dues of Active and Associate Members. Honorary Members shall pay no fees, dues, nor assessments. Members elected shall pay one-quarter, one-half or three-quarters of the annual dues according to the quarter in which they were elected.

ARTCLE XV.—SPECIAL ASSESSMENTS.

Special assessments shall be levied upon members only by resolution of the Club. No such resolution shall be acted upon at the meeting at which it is presented, but must be laid over until the next meeting, and in the meantime every member must be duly notified by the Secretary that such proposed assessment will come up for consideration. Active Members not present shall be allowed to vote upon all proposed assessments by letter addressed to the Recording Secretary, who shall cast such vote for them.

AMENDMENTS.

Amendments to the By-Laws must be proposed in writing by at least three Active Members of the Club at any regular meeting, and adopted by a two-thirds vote of the Active Members present at any subsequent meeting, provided that a written or printed notice of such amendment be sent to each Active Member with notice of meeting. Signed by M. E. RAWSON.

JOHN WHITELAW.

M. W. KINGSLEY.

[*Adjourned.*] M. W. KINGSLEY, Rec. Sec'y.

AUGUST 12, 1884:—Regular meeting held, President Holloway in the chair.

Minutes of last meeting read and approved.

The following resolution was adopted :

Resolved, That when the Club votes upon the proposed amendments to the By-Laws, the vote be taken upon such amendments as a whole, and not by sections.

On motion, the amendments to the By-Laws, as proposed at the July meeting, were unanimously adopted.

The Committee appointed to report resolutions expressing the sense of the Club

respecting the contemplated withdrawal of the Western Society from the Association of Engineering Societies, reported as follows :

Whereas, The Civil Engineers' Club of Cleveland learns with much regret that the Western Society of Engineers contemplates withdrawing from the Association of Engineering Societies ; Therefore, be it

Resolved, That we, the members of the Civil Engineers' Club of Cleveland, desire to record our earnest, but friendly protest, against the withdrawal of the Western Society from the Association which it has had so much to do in organizing and sustaining.

Resolved, That we most earnestly hope and do hereby request, that the Western Society may reconsider its purpose to withdraw from the Association, and that for another year at least it will join the other societies in an earnest endeavor to make our Association and JOURNAL attain a higher field of usefulness, believing that there will soon be an increase in the number of Societies, which will largely decrease the cost of maintaining the JOURNAL, and at the same time largely increase both its readers and contributors, as well as its sphere of usefulness.

The resolutions were unanimously adopted, and the President requested to forward them to the President of the Western Society.

The following books and papers were received : "Transactions of the Fourth Annual Meeting of the American Water-Works Association," "A System of Signals for Civil Engineers," by Chas. Latimer ; "A Memorial on the Life of Alexander Holley," by J. F. Holloway.

Mr. Theodore Rosenberg read a paper on "Passenger Railway Depots."

On motion the Treasurer was authorized to pay $5 to the janitor of the rooms.

The President appointed the following persons as a Committee on Reception and Introduction : M. E. Rawson, N. P. Bowler, J. W. Richardson, G. A. Hyde and M. L. Deering.

[*Adjourned.*] M. W. KINGSLEY, Rec. Sec'y.

SEPTEMBER 9, 1884 : Regular meeting held. In the absence of both President and Vice-President, C. P. Leland was elected President pro tem.

Minutes of last meeting read and approved.

Horace L. Emory was elected an Active Member of the Club.

Mr. J. H. Sargent read a paper entitled "The Prevention of the Pollution of the Cuyahoga River." A very general discussion of this paper followed.

[*Adjourned.*] M. W. KINGSLEY, Rec. Sec'y.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. III. October, 1884. No. 12.

ANNOUNCEMENT.

On the completion of the third volume of the JOURNAL by this issue, the Association of Engineering Societies enters upon the fourth financial year of its existence.

Those who are members of the Societies belonging to the Association do not need to be told of the degree of success thus far attained by this rather novel undertaking, nor do they need to be reminded of the desirability of extending its field of usefulness.

There are, however, hundreds of Engineers in the country who seldom if ever see a copy of the JOURNAL, and who are but meagerly informed as to the object of the Association and what it has thus far accomplished.

To such this announcement is particularly addressed.

The Societies the names of which appear on the cover at present constitute the Association. The JOURNAL is issued monthly, and is sustained by the several societies *pro rata*. The general verdict, that no society publication in the country has contained as much valuable matter during the last three years as this JOURNAL, we believe to be a correct one.

So far as we are aware, it is the only publication of the kind that is open to general subscription. Its subscription price is three dollars per annum—simply the cost of publication.

The matter mostly comes fresh from Engineers engaged in professional practice. Being a record of problems solved, difficulties overcome, and of the methods adopted in carrying out new work, such literature is the most valuable that is to be had, much of it being of permanent interest.

The membership of the Associated Societies is not confined to Engineers engaged in any one class of practice, but it may be said to cover the whole range of modern engineering.

While this much is true of the past, it is the intention that in the future the JOURNAL shall possess still greater claims upon the support and patronage of the engineering public.

With the beginning of the fourth volume, the JOURNAL will contain an Index of Fragmentary Engineering Literature, such as society papers, reports, etc., with short explanatory notes, conveying such information

as will enable the reader to judge of the scope and value of the papers, or reports, thus indexed.

In some cases of greater importance careful abstracts will be given.

It is hoped by such means to make this journal a medium by which a knowledge can be gained of the work being done by engineers in all the important fields of engineering practice.

Few persons have an opportunity of knowing what is contained in municipal, state and government reports; reports of boards of health, special commissions, and the numerous society publications of the country.

Such reports and papers contain descriptions of almost all the important engineering works being carried out, and hence embody the best practical results of engineering in all of its branches.

This literature, though of great value, is inaccessible as a general rule. Anything that will place it before engineers in a condensed form, that they may know where to find papers and reports upon particular subjects, must be of great use to the profession.

The JOURNAL may be had by subscription or by becoming a member of some one of the Societies belonging to the Association.

Subscriptions should be sent to the Secretary of the Board of Managers, H. G. PROUT, 18 Chambers Street, New York City.

THE THEORY OF THE POLAR PLANIMETER.

BY FRED BROOKS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read September 17, 1884.]

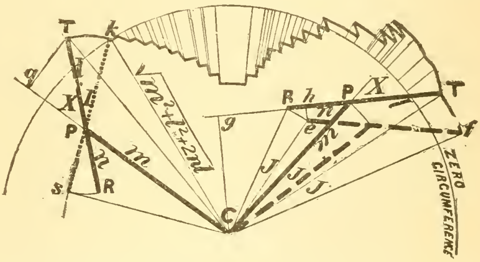
Presuming that the form of the instrument is sufficiently familiar to make a lengthy description unnecessary, C in the figure represents the point where it is fastened to the paper; and C P the arm, of fixed length m, whose only motion is that of revolution on C as a centre; hence P moves in a circular arc. R T is the other arm, revolving on P as a centre, and carrying at the fixed distance R P $(= n)$ from P a rolling wheel whose periphery touches the paper at R and whose axis is parallel to R P. R T also carries at a distance T P $(= l)$ from P the tracing point, T; l is a constant while the instrument is in use, though capable in the best instruments of having different values given to it for different purposes.

T and R can move nearer to or further from C only by the motion of the arm T R on P as a centre varying the angle X. The distance C T $= \sqrt{(m + l \cos. X)^2 + (l \sin. X)^2} = \sqrt{m^2 + l^2 + 2\, m\, l \cos. X}$, as may be seen by dropping a perpendicular T q from T on C P produced.

To every particular value of X correspond particular values of C T, C R, angle C R P, etc.; and successive small variations in X are accompanied by successive small variations in those quantities. When T, starting at any given distance from C, is moved through any path to the same or another place equally distant from C, the usefulness of the instrument depends upon X's coming back to its first value by passing in reverse order through the changes it has once made. This is secured by the usual construction of the instrument, which prevents T and R from

crossing the line of C P ; in other words X, expressed as arc to radius unity, is never less than o nor more than π (a half circumference).

The only motion possible besides those above described is the turning of the rolling wheel on its axis, which is produced by whatever motion R makes perpendicular to R P, that is, tangential to its periphery; but the wheel does not turn for any motion of R in the direction R P, which is parallel to the axis. Suppose for simplicity that the periphery of the wheel has a length of one unit and that the number of turns and fractions of a turn it makes upon any trial is recorded ; for whatever the size and graduations may be, a simple calculation would reduce the results to the required equivalents. To illustrate, let the arm R T turn on P as a centre, while C P remains fixed, from the position of the full line to that of the dotted line $s\ k$; R moves to s, describing an arc which is everywhere at right angles to its radius R P ; hence the record of the wheel is the length of the arc R s. On the other hand, supposing that Cs P is a right angle $\left(\frac{\pi}{2}\right)$ and cos. C P$s = \frac{n}{m}$, let both arms revolve around C with X fixed equal to C P s; the wheel is at every point moving parallel to its own axis and its record is zero. The distance C k of the tracing point from C in this case may be found by substituting the value $\frac{n}{m}$ for the cos. X in the general expression for C T, which gives $\sqrt{m^2 + l^2 + 2\,n\,l}$. The circumference described by the tracing point with this radius may be called the *zero circumference.*



If both arms similarly revolved around C with X fixed at any other value between o and π, the axis of the wheel would make an oblique angle with the direction of R's path, and the wheel would partly roll and partly slip. The further C R P varied from $\frac{\pi}{2}$, the less in proportion would be the slipping component, and the greater the rolling component and the record of the wheel. With C R P $> \frac{\pi}{2}$, T would describe an arc outside the zero circumference and the wheel would make what we will call a positive record. With CRP $< \frac{\pi}{2}$, T would describe an arc inside the zero circumference and the wheel would turn in the contrary direction, which we will call negative ; *provided*, that T revolved in the same direction in both cases. Motion of T through any arc in the direction of the hands of a watch may be considered positive ; then motion of T in the opposite direction over the same arc back to its starting place must be

considered negative, and would obviously be attended by a turning of the wheel equal in amount to that attending the positive movement, but with its direction reversed.

In the practical use of the instrument T may move over any path, near enough to the zero circumference to be reached, whose beginning and end are equally distant from C. Hence X is the same at the end as at the beginning. The record thus made is proportional to the area included between the zero circumference and T's path and the radial lines through its beginning and end from the centre C, as will now be explained.

T's path may be resolved into an infinite number of parts, consisting of infinitesimal arcs (I) described from P as a centre by changes in X, C P being fixed, and of infinitesimal arcs (J) described from C as a centre with X fixed. This is illustrated by large arcs of the two classes on the diagram. The area in question may be correspondingly divided into elementary portions (illustrated by the large divisions made on the diagram by fine radial lines) each of which may be described as *plus* the area included between one of these infinitesimal arcs and radial lines through its extremities from C, *minus* the sector included by the same radii and an arc of the zero circumference. Hence the area is a minus quantity if T moves inside the zero circumference, positive if outside; *provided*, that T moves around C in the direction of the hands of a watch. If T moves around C in the contrary direction, both the signs in the above expression are to be changed: for as the area of a sector is equal to its arc multiplied by half its radius, the area becomes negative when the arc becomes negative. If this be borne in mind it will be seen that the algebraic sum of all the elements corresponding to the *second* term in the above expression is the sector of the zero circumference included by radii passing through the points of beginning and ending of T's path; and that the algebraic sum of all the elements corresponding to the *first* term is the area inclosed by T's path and lines from C to its beginning and end, however irregular T's path may be.

We will first consider that class of infinitesimal arcs (I) and corresponding elements of area, due to changes in X alone. Their accumulated effect upon the area is zero, and upon the record of the rolling wheel is zero. As to the wheel, from the condition that X passes again in reverse order through the changes it has once made, it follows that for every infinitesimal motion, like Rs, of R, recorded by the wheel for the infinitesimal change (I) between two consecutive values of X, there must be in some other place a motion in the opposite direction of the same magnitude for the infinitesimal change back again between two consecutive values of X equal to the former pair. As to the area, each infinitesimal arc I (like Tk) has, as previously stated, its corresponding element of area; and the equally large arc with the contrary sign just now referred to, in another place where X has the same values, must also have its corresponding element of area, exactly as large as the former, but with its algebraic sign reversed. The effect of the first class of elements into which T's path was resolved is thus eliminated.

Hence the total record of the wheel for T's whole path is the record due to the second class of its elements, the infinitesimal arcs (J) described

from C with X fixed for each; and the total area included between the zero circumference, T's path and the terminal radii, is the sum of all the elements of area corresponding to this second class of arcs (J), which we have now to consider. J expresses in terms of arc to radius unity any infinitesimal angle T C f between radial lines passing from C through the extremities of an infinitesimal arc T f. The corresponding element of area is the difference between the sector T f C and the sector included by the zero circumference and the same radii. Making use of the algebraic expressions given above,

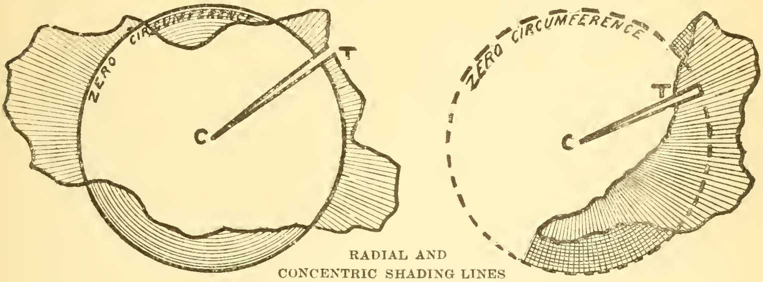
from $\frac{1}{2} J \times (m^2 + l^2 + 2 (m\, l \cos. X)$

subtract $\frac{1}{2} J \times (m^2 + l^2 + 2\, n\, l)$

and the difference, $J \times l \times (m \cos. X - n)$

is the required element of area.

The corresponding record of the wheel is made by the motion of R through the path R $e = J \times$ C R. This path may be resolved into two components, R h, which has no effect upon the record, and h e, which is the record $= J \times$ C R $\times$ cos. (π — C R P). By dropping the perpendicular C g upon P R produced it will be seen that C R cos. (π — C R P) = R g = m cos. $X - n$. Hence record of wheel is $J \times (m \cos. X - n)$. Therefore the



RADIAL AND
CONCENTRIC SHADING LINES
DENOTE AREAS OF CONTRARY SIGNS.

element of area corresponding to any infinitesimal arc, J, is just l times the record due to the same arc; hence the sum of the elements of area for all the arcs (J) is l times the total record corresponding, which is the essential thing that was to be proved.

In the application of the instrument to get the area of a closed figure, T's path ends in the same point where it began, and we have two cases according as this is accomplished by C P's making a complete revolution around C, or by its moving backward as much as it has once moved forward. This may be better understood by reference to the accompanying diagrams, in which T's path is shown not quite completed. In the first case, C is within the figure; in the second, outside. In both cases the area between T's path and the terminal radii is the area of the closed figure. The sector within the zero circumference, which we have been deducting, is in the first case the whole circle $\pi \times (m^2 + l^2 + 2\, n\, l)$; in the second, nothing. Hence add $\pi \times (m^2 + l^2 + 2\, n\, l)$ to l times the record in the first case, and add nothing to it in the second, in order to get the required area of the closed figure.

My friend, Mr. Frank S. Hart, of the Locks and Canals office at Lowell, drew my

attention to this subject by showing me a simple proof of the method of the planimeter. I suggested some alterations and abbreviation in it, and with his kind permission I present this paper, hoping it will interest others who may have been using the instrument without studying out its principle. Though I should naturally suppose that all desired mathematics of the planimeter could easily be found elsewhere, no one of the published discussions (mentioned below) that I have met with fully satisfies me. F. B.

Amsler's Planimeter, being pp. 623–9 of Dr. F. A. P. Barnard's "Machinery and Processes of the Industrial Arts, and Apparatus of the Exact Sciences," which occupies the third volume of the Reports of the U. S. Commissioners to the Paris Exposition of 1867.

On Amsler's Planimeter. By F. J. Bramwell, C. E., beginning at p. 401 of the 1872 Report of the British Association for the Advancement of Science.

An abstract of this is given (pp. 252–6) in the fifth edition of William Ford Stanley's Mathematical Drawing Instruments, published by E. & F. N. Spon, 1878, where it is followed by an account of Amsler's Integrater, for giving, in addition to the area of any plane surface, its static momentum and its moment of inertia in relation to any axis.

Planimeter. Spon's Dictionary of Engineering.

The Planimeter, pp. 59–61 (contributed by Wm. D. Gelette, C. E.) of Buff & Berger's Handbook and Illustrated Catalogue of Engineers' and Surveyors' Instruments.

HISTORY OF CLEVELAND PAVEMENTS.

By M. E. Rawson, Member of the Civil Engineers' Club of Cleveland.

[Read February 14, 1882.]

A City is known by its Pavements.

The history of every city is written upon its streets. Its eras of prosperity and of adversity, too often of unwise economy or reckless extravagance, are written nowhere else more clearly than here. Each street is a page in the municipal calendar upon which all people may sit in judgment, and that judgment is invariably for improving its condition. In this all people in all cities agree, but it is hard to find in any city a single street on which all agree as to how it should be improved

It is much easier to recognize the necessity for improved roadways. than to improve them. The how-best-to-do-it and with what materials stands to-day almost as much an unsolved problem as it did fifty year, ago, and yet very much has been gained, in learning what material to use and what not to use for street pavements.

Cleveland, considering its area, wealth and population, is far behind most cities in its mileage of street pavement, a fact not easily explained when we note the rapidity of its growth from a city of 44 or 45 thousand inhabitants in 1860 to nearly 200,000 in 1882 counting all those who traverse its streets, especially when increased traffic means increased traffic ways.

It is therefore hard to see why Cleveland, with her four and one-quarter hundred miles of streets, has less than one-eighth of them paved at all, and that little better than one-half of those are to-day well paved. Two causes have doubtless contributed to this disparity. The fact that most of the streets in the city proper are upon a plateau, from 70 to 100 feet above the lake and river level, and are mostly of good material and well drained ; and secondly, that a very considerable percentage of the present mileage of city streets is due to the frequeut annexations of territory, which added streets and people, but not pavements.

Incoroporated as a village in 1814, passed to a city in 1836, and suc-

cessively enlarged by annexation in the years 1850, 1854 when Ohio City was added, 1864–7–9, and finally by the addition of the village of East Cleveland and parts of Newburg and Brooklyn townships in 1872, and the village of Newburg in 1873.

All of this brought miles of unimproved streets and good broad acres of ground, increasing the area of the city to nearly 17,200 acres, but with the exception of a single street from East Cleveland, added not one square yard of pavement, either good or bad.

In giving the following history of the early city pavements, I do so from the best information attainable from the limited time which I could give to the research, and I give it without always attempting to give a reason for the successes or failures which have followed street pavements from first to last.

If, in making any statements here, I am in error as to *facts* or *dates*, I shall be pleased to be interrupted and corrected.

From the first the city has suffered from the want of proper paving material sufficiently near at hand to warrant the expense of its preparation and the labor of placing it upon the street. Nature, though lavish in her gifts of building stone, dealt less kindly in regard to good paving stone.

The Newburg and East Cleveland blue stone, is the nearest and perhaps the best of these native stones, for paving purposes, but it contains very little silica, the bone and sinew of all good paving stone: it is not free-splitting, a most important factor in the cost of preparation. Portions of this stone are said to be now in use in the side gutters upon Superior street, west of the park, where they were placed in the early paving of the street. This I am not able to verify—but will be pleased to record the fact if any one present can do so.

The Berea, Amherst, Peninsula and Independence sandstones are all too soft. The latter, however, deserves mention, and will be noticed hereafter. The Warren, O., flagstone, now being brought to public notice, for street pavements, was then little known, if at all, and to-day is not long tried. It has never been laid in this city, except that laid this fall around the new N. Y., P. & O. depot on South Water street.

Cobble stones were not in sufficient quantity in this vicinity to be thought of, and the city was compelled to go beyond the limits of the county and State for a proper material.

On the 26th of March, 1850, the city passed its first paving ordinances, which provided for "grading, paving and planking Superior street from the public square to the west line of Water street." This was accomplished in the summer of the same year.

The street was covered with oak plank, and remained so "paved" (with perhaps a renewal) until the year 1860, when the present pavement of Medina stone was laid, which, as many of you will remember, was in progress at the time of the inauguration of Perry's monument in the public square.

FIRST STONE PAVEMENTS.

The earliest stone pavements laid in the city were those upon Union lane and Water street, between Superior and St. Clair streets, and upon a portion of Superior street hill. These streets were paved with yellow

Independence sandstone between the years 1851 and 1854. The stones were very large as compared with the stones now generally used, being 8 or 10 × 12 inches on top by from 8 to 12 inches deep.

The pavement was only partially successful, as all soft stone pavements must be—the large stones settling out of place, forming large holes, into which the wheels dropped and pounded until the soft stones were so worn away that the pavement consisted of little else than a succession of ruts and sinkholes, and so continued, with frequent repairs, until in the year 1867, when the pavement on both streets was taken up, the blocks redressed or inverted, and relaid, but only to repeat the experience of former years. In the years 1870 and 1871 both streets were again repaved, one with Nicolson wood pavement, the other—Union Lane—by using a portion of the old and much new material; but at present little can be said of the latter, except that it is in bad condition. In three or four years at most both streets must be again repaired, and for the fourth time.

Superior street hill, fortunately for its pavement, possesses a steep grade that precludes its use as a thoroughfare, and protects it almost wholly from heavy traffic. It has had an occasional repair, and, I think, the blocks have been once relaid. It is at present in fair condition.

It is evident that the authorities began to see that success or failure depended largely on the nature of the material used, for during the years from 1855 to 1860 we find that they experimented upon a variety of stone.

About the year 1855 or 6, stone from Medina, N. Y., was tried upon the remaining portion of Superior street hill, and in 1857 upon East River street, between Superior and St. Clair streets, and although this street has for 24 years sustained some of the heaviest freight traffic in the city, it has never been repaved and only once or twice repaired, and the most of it now is in fair condition.

In 1857 and 8 Sandusky limestone was laid on Centre street, between South Water street and the river, on Meadow street, between Main and Front street, and on the south and west sides of the public square south of Superior Street. These pavements were not satisfactory, and were all removed and the streets repaved within from ten to twelve years after.

The stones, although hard, wore away fast, and split badly by the frost.

Limestone, from its nature (at least as known in this region) can never prove a very successful paving material, because carbonate of lime is soluble in water, or moisture containing carbonic acid. This acid abounds in rain water, and in its various forms of snow and ice, and in the air itself—and gives to the stones a slippery and fast wearing surface. This is said not to be an objectionable feature in the use of the harder qualities for Macadam purposes, the dissolved portions uniting with sand, which finds its way upon it, serve to form a cement, that sheds water and forms an excellent roadway.

Stone from Lockport, N. Y., was used upon the 18-foot strip in the centre of Columbus street, between Centre street and the river, about the year 1859. This stone is similiar in quality and texture to that found at Medina, N. Y., now so commonly used, and in more than twenty years of wear has shown those qualities most essential for street paving—hardness

without brittleness—wearing smooth, but always retaining its grit, and is never slippery. From this time on the good, staying qualities of the Medina stone began to be recognized, and in 1859 we find Merwin Vineyard (now South Water street) and portions of Canal and Champlain streets so paved.

Superior street from Water to Monumental Park, Water street from St. Clair to Front street, and the whole of the roadway around Monumental Park north of Superior street, followed with Medina stone in 1860, since which time, more than 20 years, no other stone has been used by the city for street pavements.

From 1861 to 1864 little seems to have been done, but in the latter year Seneca street from Superior to Champlain, Ontario street, from the Park to Huron street, Prospect street, from Ontario to Erie street, Euclid avenue, from Erie to Perry street, and Detroit street between Centre street and the south end of Cuyahoga Steam Furnace, were paved with Medina stone. The last (a short portion of Detroit street) being the finest street paved west of the Cuyahoga River.

In 1865, except the paving of St. Clair Hill between Water street and the railroad tracks, little was accomplished further than the completion of previous contracts.

WOOD PAVEMENTS.

The preceding review of the earlier stone pavements brings us to the year 1866, which marks an era in the history of street paving in Cleveland, by the introduction of wood blocks for paving purposes.

To Mr. Samuel Nicolson, of Boston, Mass., is due all the merit that exists in this system of street pavements, in Cleveland at least, which is all that concerns the present discussion of this topic.

After frequent visits to the city and with no little urgency on his part he succeeded, in the summer of 1866, in introducing the first wood blocks laid in the city, on that portion of Prospect street between Erie street and Sterling avenue.

The authorities proceeded with the improvement after having visited the cities of Detroit, Chicago and Milwaukee, where it had been laid and was becoming popular.

The contract was let to Gore Bros. & Co., of Boston, and work commenced under the direction of an experienced inspector from a neighboring city. The street was excavated to the proper depth, and at first the floor boards were laid down and mopped over with hot coal tar, but it was soon learned that dipping the boards and strips into long tanks of boiling coal tar was much quicker and more effective.

The 6-inch paving blocks were sawed on the street from 3-inch pine planks by Mr. James Gloyd with the aid of his pile-driver engine and men, who as the work progressed resolved his *stationary* engine into a *portable* one by using the sidewalks as tramways, attaching one end of his great pile-driver rope to a friendly tree, the other to the drum of his driving wheel. The engine started and, if both rope and tree held, a forward movement was made and a new location secured in front of some other man's lot, and of course upon his choicest grass-plat.

We smile now at these rude appliances used in laying our first wood pavements, as compared with the costly plant used by the modern con-

tractor in the preparation and treatment of his material and in the construction of his work.

The position of city engineer in those early days of inexperience was not always a comfortable one. I very well remember those first few days in the paving of Prospect street, when long rows of friendly taxpayers and sympathizers lined the curbstone upon each side of the street, full of advice and direction, of remonstrance and threatened injunction.

This manner of slow-going was not successful financially, and the contractors gave up the work, which was completed the year following by McNairy, Claflin & Co., of this city.

Thus ended the *first* of the long lessons in wood-paving that lasted for ten years. It is a singular fact that the repaving of this same portion of Prospect street should be the *last* lesson in this costly luxury; for it is a luxury when it is new and well done, as all must concede.

Royalty.

On the 31st of August, 1866, the city secured from Mr. Nicolson the exclusive right to lay his pavement in the city for $2,300: the patent having two years to run, expired August 8, 1868. This was considered at the time a very satisfactory transaction, in view of the amount of work that was even then plainly foreseen, and upon which it was believed Mr. Nicolson could and would claim a per-yard royalty. After the re-issue of his patent the city effected a new purchase of the right to pave under it from the heirs, Mr. Nicolson having in the meantime died.

This purchase was effected by the Hon. Amos Townsend, then President of the City Council, for the sum of $30,000, payable within two years, in city bonds. This agreement was confirmed by the City Council, August 9, 1870, and secured to the city the full rights for the full term of the reissue.

The city sought to reimburse itself for the amount paid by charging the property 15 cents per square yard extra upon each street so paved.

Wood pavements were laid in greater or less amounts from 1866 to 1877, both years inclusive, and were all what is commonly known as Nicolson pavement, although varying somewhat from time to time, except upon that portion of Broadway between Union and Miles streets, and upon Franklin avenue between the Circle and Harbor street, where the Miller wedge block was used.

Preserving Process.

Previous to 1871 all wood pavements laid were treated with coal-gas tar by immersing the floor-boards, inch strips and the lower or both ends of the blocks in tanks of boiling tar, and, after laying, by filling the interstices above the strips with coarse gravel, or, more properly, pebbles and boiling tar, except upon Superior street east of Erie street, and on Euclid avenue east of Wilson avenue, where only the floor-boards and strips were so treated.

Resin Process.

In paving St. Clair street, between Erie street and Wilson avenue, and Detroit street, between the old and new city limits, in 1871, the wood was treated with what is known as the *Resin Process*, which consisted in

immersing the wood in a hot solution composed of wood resin dissolved in benzine, in the proportion of 4 pounds of the former to one gallon of the latter.

The wood was kept in the solution at a temperature of 160° Fahr. (the boiling point of benzine), "a sufficient time" (as the specification reads) "to thoroughly repel the sap in the wood, and until it shall have absorbed resin in the proportion of 16 pounds to the square yard."

This process, whatever merit it might have possessed, had it been thoroughly applied, was doomed early to give place to its more formidable rival, the

Thilmony Process.

In 1872, Mr. Wm. Thilmony, a relative of the inventor of the process bearing his name, obtained permission to apply his treatment upon that portion of St. Clair street (then being paved under the resin process), between Minnesota and Alabama streets, a distance of about 270 feet.

About this time Mr. Thilmony succeeded in organizing a company with sufficient wealth and energy to erect a costly plant and hold the ground against all competitors from 1872 to 1877, with a single exception, that of Franklin avenue, between the Circle and Harbor street, where the Seely & Pelton dead-oil process was used.

So far as I know, this city was the first to apply the Thilmony treatment to pavement blocks, although it was claimed to have been long in use in Germany, for treating railroad ties, bridge timbers, etc.

From 1872 to 1877 this company treated 189,961 square yards of pavement in this city. How much this treatment added to the cost of the pavement, I am unable to state, as one firm was enabled to underbid all others, and did all the work. The price given to bidders was about $12 per thousand feet of lumber treated, if I remember correctly.

The following table shows all the streets and parts of streets upon which the Thilmony process was used, with cost per square yard of pavement (including royalty) and the year in which it was laid :

Street.	From.	To.	Ft. long.	Year.	Cost.
St. Clair street....	Minnesota.......	Alabama...	270	1872	$2.55
Perry "	Prospect........	Woodland.......	2,722	1872-3	2.47
Ontario "	Park............	St. Clair..........	349	1872-3	2.63
Garden "	Brownell.... .	Wilson...........	7,329	1873	2.57
Franklin avenue.......	Harbor..........	Waverley.......	2,873	1873	2.57
Wood street............	Superior	St. Clair..... ..	616	1873	2.63
Broadway	Independence....	Union.....	10,116	1873-4	2.63
Kinsman street........	Wilson...........	City Limits......	9,100	1874	2.53
Detroit "	Kentucky........	Waverley........	3,592	1875	2.21
Broadway..	Union	Miles	9,173	1875	2.61
Brownell street....	Euclid...........	Scoville..........	2,085	1875	2.35
Woodland avenue.. ...	E. Madison......	Wood Hills.....	4,832	1875-6	2.25
St. Clair street.........	Erie..............	Wood............	1,086	1876-7	1.93
Perry "	Woodland........	Broadway.......	904	1876-7	1.90
Prospect "	Erie.....	Perry....	3,132	1876-7	1.91½
Total... ....11.0 miles.					

The average cost was about $2.50 per square yard, the highest being $2.63, and the lowest that upon the last streets paved, from $1.91 to $1.93 per square yard.

The process as used in this city was substantially as follows :

The material, after having been cut ready for laying upon the street, was placed in a large cylindrical copper tank about 5 feet in diameter by about 50 feet long, provided with a movable head, fitting air tight, steam coils, vacuum and force pumps. The blocks were then steamed, and treated with baths of sulphate of copper (blue vitriol) and chloride of barytes.

The *claim* for this treatment in substance is, that sulphate of copper is a powerful antiseptic, but is soluble in water. By the introduction of the chloride of barytes in the proportion of 2½ of the former to 2 of the latter, *sulphate* of barytes, or salts of barium, is formed, which is *insoluble* in water.

The first effort was to dispel the sap by a direct steam bath, kept at 18 pounds pressure for 1¾ hours. The steam was then turned off and the condensed steam and coagulated sap drawn off at the bottom of the tank. The vacuum pump was then applied, and the air exhausted up to a 5-inch pressure, after which a warm solution of sulphate of copper and water was introduced, sufficient to cover the blocks, and was expected to find its way into the blocks by capillary attraction, to aid which, and to save time, the force pump was applied, and the pressure kept at 100 pounds for four hours. The remaining solution was then drawn off for further use, and the tank refilled with a cold solution of chloride of barytes, the vacuum and force pumps being used as before, to accelerate the process of absorption. When this was accomplished, the blocks were removed, and were ready for use.

The Seely & Pelton Process,

as used on Franklin avenue, does not materially differ in the mechanical part from that just described, but differs in the chemical solution used, which consists of what is known as dead oil, a distillate of coal tar, and so called because of its density, being heavier than water.

This is sometimes called the "creosoting process," from the amount of creosote contained in the dead oil, but differs materially from the Hayford process bearing that name.

There are 5,058 square yards of pavement upon this part of Franklin avenue treated with the dead oil process, at a cost of $3.00 per square yard, including royalty upon both treatment and pavement. This is laid with the Miller Wedge Block, with the *interstices* filled with a concrete composed of hot coal-tar, gravel, lime and sulphur.

This pavement, laid nine years ago, shows wear and depressions upon its surface, but no decayed blocks were to be found in an examination made last year by the City Engineer and myself, and it has never been repaired.

Of the 547,242 square yards of wood pavement laid in the city, 258,297 square yards were treated with gas tar, in the usual way ; 49,320 square yards were treated with the resin process, 189,961 square yards with the Thilmony process, 5,058 square yards with the Seely & Pelton process, and 44,600 square yards have *no* treatment.

CONCRETE PAVEMENTS.

The only concrete pavements laid in the city are those known as

Abbott's concrete, except small blocks of a few yards laid as samples, one of which is in front of St. Paul's church on Euclid avenue, where the top coat is laid with Trinidad asphalt.

The base of this pavement, known as Abbott's Concrete, is coal tar, and only differs in the manner of treating the material used, and possibly somewhat in the laying, from all others of its class. The manner of its construction was in substance as follows :

The street was brought to the proper sub-grade, thoroughly puddled, and then rolled with a 17-ton steam roller ; upon this sub-grade a foundation composed of broken stone and concrete was laid, 6 inches deep when rolled. no ballast being used under it.

This foundation was thoroughly compacted with the roller, and then covered with a 3-inch course of the concrete mixed with fine roofing gravel. The mixture was applied hot, in a granulated state, and immediately rolled. The pavement was then covered with a grit coat, as it was called, made by mopping the surface with liquid concrete, then covering it with fine roofing gravel, and a finishing coat was given by dusting over the surface with powdered water lime, for a coloring rather than a covering, I presume.

All of these pavements were laid between and including the years 1873–75, the first laid being upon Prospect street, between Case avenue and a point 340 feet east of Kennard street, followed by Euclid avenue, beyond Fairmount street, laid in 1873–4 over the Macadam. which latter had begun to fail before the contract was completed.

In 1875 the experiment was tried of placing a 3-inch covering over the partially decayed and worn wood pavement upon Superior street, between the Park and Erie street, and upon Euclid avenue, between Perry street and Wilson avenue. This was done by removing the worst of the decayed blocks, filling the holes and depressions with broken stone, and then covering the whole with a 3-inch course of concrete, which was rolled with the steam roller as in other cases ; 40,643 square yards (about 1 4-10 miles) were laid in this manner at a cost of $1 per square yard.

These pavements, with frequent repairs have lasted only about 6 years, they were laid as experiments, and have served that purpose at least. One fact we learn—that the concrete covering has seemed to arrest almost entirely the decay of the blocks, which appear in about as good condition today as when covered, 6 years ago. Both streets are now ordered repaved.

The concrete pavements laid on the easterly ends of Lake and Prospect streets in 1874 are the best samples of this pavement laid in the city. The latter street, I think, has never been repaired—except for the caving in of a sewer, and the former requires only light repairs. All others receive extensive yearly repairs, but I am not able to give the amounts or averages correctly.

There are 39,741 square yards, or about $2\frac{3}{10}$ miles of streets and parts of streets paved with concrete on stone foundation, at an average cost of $2.39 per square yard, and $1\frac{4}{10}$ miles on old wood foundation.

Concrete pavements possess merit enough to make them popular if they were always laid as well as they may be. When properly made they possess a smooth, easy rolling surface, almost noiseless for vehicles, are easily cleaned and repaired, absorb no moisture or liquids from the street

and emit no poisonous vapors. But they can never be so well made as not to get dusty, for if there is no perceptible wearing of the surface, the droppings of horses, dirt and gravel from wagons and adjacent streets are ground to powder between the smooth surface and passing wheels, that grind like the upper and nether millstones, there is no escape. The dust is much finer ground than upon other pavements, where the particles escape between the rows, and the lightest wind takes it up.

The remedy lies in cleaning and sprinkling, or, better still, in sweeping, and upon no other pavements can this be so easily and effectively done.

Abbott's concrete is, perhaps, as successful as any of the coal-tar pavements, which, at best, can never attain the perfection of the asphalt pavements of Europe, especially of Paris, so often referred to as the ideal pavement.

Coal tar at best is volatile, and if distilled at a high temperature before using, it can never be so completely done as to drive off *all* that is volatile, without greatly destroying its adhesive properties, when it must crumble and break.

I believe it may be successfully used for the sub-portions of pavements, which shall then be covered to a depth of from 1½ to 2 inches with genuine asphaltum, and thus provide a good pavement at a moderate price.

MACADAM PAVEMENTS.

Broken stone pavements here have not been successful for the want of proper road metal.

Euclid avenue, east of Fairmount street, as stated, failed, or rather its failure became so apparent, even before the Macadam contract was completed, that it was at once covered with concrete at the request of property owners, at an additional cost to them of $1.25 per square yard.

East Madison avenue, between Euclid avenue and Superior street; Woodland avenue, between Wilson and East Madison avenue, and Chestnut Ridge street, between Lorain street and the C., C., C. & I. R.R., are all so paved, and except the last, with the hardest of the East Cleveland bluestone, all to a depth of about 12 inches when rolled.

The surface of the stone upon East Madison avenue was covered with 2 inches of hard black shale, but it soon ground to clay and was really of little use, and the whole street rutted and wore away badly.

Woodland avenue was covered with 4 inches of chips, or spalls, from Medina paving stones, which helped to make it the most of a success of any of them, but has frequently to be repaired or resurfaced.

TELFORD PAVEMENTS.

Fairmount street, from Euclid avenue southerly to the City Limits, and Cedar street, between Wilson avenue and Fairmount street, are paved with Telford, which differs from the Macadam in having its lower 6-inch course laid with flat or flag stones, placed compactly together for a flooring, upon which broken stone and gravel, or clay, was placed and rolled.

These two streets were constructed by East Cleveland village just previous to annexation, in 1872; with the same material as used for the Macadam streets referred to, and with about the same results.

The stones for both Macadam and Telford streets were all hand-broken,

except for Woodland avenue, where a Blake crusher was used, and, as I am satisfied, to the injury of the material. Stone broken into cubes by sharp, quick blows, is stronger than when *crushed* by slow pressure, which breaks the bond that exists in all stone, and which must be maintained for Macadam, as well as for any other pavement.

This is better illustrated by taking pieces of glass, very hard ice, or other transparent substances, and breaking or cracking them by sharp, quick blows, and also by slowly crushing them—when all fractures both within and without may be seen.

The prices paid for Macadam were from 13½ to 16½ cents per square foot and for Telford (owing to the nearness to the quarries), from 10 to 11 cents per square foot, not including excavation, and were all constructed between 1872–74. There are about three and one-half miles of the former and three and one-tenth of the latter, and cost in the aggregate $181,300.

I am unable to give the cost of repairs from year to year.

LATER STONE PAVEMENTS.

We now return to stone pavements proper, as now laid.

I think there can be little question that the standard of stone pavements has been raised materially in the last few years, if we except a few instances of the first Medina stone pavements laid between 1860 and '63—which after 20 years' wear, are in such good condition as to promise another 20 years. Among these may be mentioned the east, north and west sides of the Public Square, Superior street west of the Park, South Water, Merwin, and the central portion of Columbus street, between the Bridge and Centre street, and Water street north of St. Clair street.

The streets have a superior foundation, but the stone, although in most cases of excellent quality, is found, when taken up, to be inferior to that now used, in depth, uniformity and dressing.

In most of those early pavements the road-bed had never been disturbed before they were laid, and for a number of years after, few disturbances occurred as compared with the continual disruption of the road-bed now, both before and after the pavement is laid, in the construction and repair of sewer, water and gas pipes and street railroad tracks.

No care upon the part of the engineer, or fidelity of the contractor can preserve the even surface of any pavement under this scarifying process.

There are three forms of laying stone pavements in this city. The common (wet), dry and dressed block, the general features of which are in substance as follows:*

Common (or wet) paving, so called because of its more common use, and "wet" because the wet or fresh ballast is allowed to be thrown upon it with the iron pavers, as the stones are laid; while in "dry" paving no ballast is allowed upon the top as the work progresses, but, like a dry

*In each case the streets are brought to the proper depth of sub-grades, and thoroughly puddled with water, by damming-up the roadway in sections of about 50 feet, and filling with water from curb to curb. Upon this sub-grade, when sufficiently puddled, a bed of ballast is placed, consisting of clean bank gravel, 10 and 12 inches in depth, under the stone, upon which, when properly prepared, the stones are placed.

wall in masonry, no filling is used at the time of laying, which allows a perfect inspection of the work at all times.

The specifications for common pavement call for stones from 2 to 4 inches thick, 6 to 10 inches long and 8 inches deep; smoothly broken so as to make close joints down two inches, and they must rest against each other when laid.

In former pavements no particular treatment of the ballast was required after it was put in place. The specifications for *future* work provide for sprinkling and rolling the ballast to decrease the after-settlement.

DRY-PAVING

specifications provide for about the same size and depth of stones, but call for better dressing. Closer joints are required, no small stones are allowed and much more care is required in setting them; and, as stated, no ballast is allowed upon the paving as the stones are laid, which allows of much closer inspection. The ballast for both kinds of pavement is 12 inches deep underneath the paving.

Bank gravel is used here exclusively for all kinds of stone paving ballast.

Lake sand is successfully used in Buffalo and other cities for this purpose, and will doubtless be so used here before long, as gravel is becoming scarce, as compared with former years, when it could be had for the hauling.

DRESSED-BLOCK

paving specifications call for stones from 3 to 4 inches thick, 6 to 10 inches long and from 6 to 7 inches deep. They are to be rectangular blocks, with joints reduced to $\frac{1}{2}$ inch in laying, top and sides of stones to be "axed" off smooth, the ballast to be not less than 10 inches deep underneath the stones, when rolled. Two inches less of ballast is allowed than for either common or dry paving, because of the broader beds of the stones and the greater care taken in puddling and rolling the ballast. The stones are laid *dry* or without ballast on top during construction.

Stone pavements of all kinds are rammed two or more times when laid, with a heavy wooden rammer, from 70 to 90 lbs. in weight, no iron being allowed upon its lower face to come in contact with the stones. A light top dressing of gravel is placed on top of the paving when laid, swept into the joints with a steel splint broom and then washed in with water, to insure the thorough bedding of the stones. This is done both before and after ramming, and continued until no more can be forced into the joints.

In the case of the dressed block paving the gravel filling is left 5 inches below the top of the stones, and when dry the balance of the space is filled with a hot composition consisting of gas tar distilled at a temperature of not less than 600 deg. Fahr., to which is added 10 per cent. of refined Trinidad asphalt, and the whole thoroughly mixed with such proportion of still-wax as will prevent the mixture from becoming either soft or brittle under the influence of heat or cold. The mixture is applied at a temperature of not less than 300 deg. Fahr., filling the joints to the top. This sets hard in an hour or two, and after the light gravel dressing is applied the pavement is ready for traffic.

The concrete filling used in dressed block paving, so long as its retains its tenacity, renders it wholly impervious to water, deadens the noises bonds each stone to its neighbor, and is to the pavement what good mortar is to masonry.

This pavement was first laid upon the viaduct in 1878, embracing about 11,400 square yards, and cost $2.50 per square yard, including ballast and filling. Last year (1881), 5,755 square yards of this pavement were laid in Superior and Ontario streets through the Park, at a cost of $2.70 and $3.10½ per square yard respectively.

The *dry pavement* streets are Euclid avenue, from the Park to Erie street, laid in 1873–74, and cost 26 cents per square foot, being far below its real cost; Bolivar street, from the market to Erie street, laid in 1874, price 34½ cents per square foot, and Eagle street, from Woodland avenue to Erie street, paved in 1875–76, price 29⅞ cents, giving a total of 17,450 square yards.

All other stone-paved streets in the city were laid with common paving, embracing 30.4 miles of streets wholly or partly paved in this manner, at an average cost on 100 contracts of 18.1 cents per square foot.

I have been unable to get any satisfactory data as to the cost of stone repairs, except for the year 1879, as this work is done by a repair department, which is almost wholly occupied in replacing street openings, occasioned by the laying and relaying of gas, water and sewer pipes, where the cost is charged directly to the party in whose interest the work is done, and not to the city.

During the year 1879 the sum of $7,900 was expended by contract on stone repairs, at an average cost of 3.2 cents per square foot.

The city *contemplates*, and has now advertised the repaving of about a dozen of the worst of the wood-paved streets, aggregating about one million square feet.

The city will pay one-half of the expense of such repaving, and assume the care and maintenance of the streets afterward.

This substantially concludes the history of Cleveland pavements, past and present. What the *future* pavement will be, the wisest cannot tell.

I have intended in this paper to give *facts* only, but hope at some future time to give some of the conclusions I have reached in studying the history of our city pavements, their mode of construction, the material used, the various wood-preserving processes employed, and the manner in which these costly improvements are paid for.

STABLE CONSTRUCTION.

By Augustine W. Wright, Member Western Society of Engineers.

[Read July 15, 1884.]

The United States Census of 1870 gave the number of horses owned in the U. S. as 8,690,219. When the Census of 1880 was taken there were 12,170,296 horses, mules and asses on the farms alone. Our own State of Illinois leads with 1,146, 360 !

Anything affecting the monetary value of this vast multitude is of im-

portance to the individual owner, to the State wherein he resides, to the nation of which he is a citizen !

We appeal in vain to history to inform us when mankind first subjected this, the most noble of the brute creation, to his service in times of peace and times of war ! The date is lost even to tradition, but that he served in the dawn of mankind, the sublime words of Job bear witness.

"Hast thou given the horse strength? Hast thou clothed his neck with thunder? Canst thou make him afraid as a grasshopper? The glory of his nostrils is terrible. He paweth in the valley, and rejoiceth in his strength ; he goeth on to meet the armed men. He mocketh at fear, and is not affrighted ; neither turneth he back from the sword."

Prescott tells us of his service with the Spaniards in their conquest of Mexico. In short, the debt of humanity to this noble animal cannot be overestimated, and every language has been used to sing his praise ! !

The artificial restraint imposed upon the horse by mankind during so many centuries past has had its effect, and he resembles his master in many diseases.

From a sanitary point of view late years have witnessed great advancement in the construction of buildings for mankind, and the cry for better stable accommodations has not been uttered entirely in vain.

Permit me to quote a few from the many writers upon this important subject.

John Stewart wrote : "Stables have been in use for several hundred years. It might be expected that the experience of so many generations would have rendered them perfect. They are better than they were some time ago. * * * A damp stable produces more evil than a damp house. * * * Since 1788, when James Clarke's work was published protesting against close stables, there has been a constant outcry against hot, foul stables. Every veterinary writer who has had to treat of diseases has blamed the hot stables for producing at least one-half of them." Jennings wrote : "The most desirable thing in a stable is ventilation. A horse requires air equally with his master ; and as the latter requires a chimney to his sleeping room, so does the former." Henry W. Herbert, better known as Frank Forester, wrote : "In a climate so uncertain, changeful, and in which the extremes of heat and cold lie so far apart, as in this country, the question of stabling is one of paramount importance. The stable, to be of real utility, must be perfectly cool, airy, and pervious to the atmosphere in summer ; perfectly close, warm, and free from all drafts of external air, except in so far as shall be needed for ventilation, in winter ; perfectly ventilated, so as to be pure and free from ill odors, ammoniacal vapors and the like arising from the urine and excrement of the animals, at all times perfectly dry under foot and well drained, since nothing is more injurious to the horse than to stand up to its heels in wet litter. * * * Lastly, it should be perfectly well lighted, as well as thoroughly aired."

Stonehenge wrote : "The horse, like all the higher animals, requires a constant supply of pure air to renovate his blood, and yet it must not be admitted in a strong draft, blowing directly upon him, or it will chill the surface and give him cold. * * * By common consent it is allowed

that no stable divided into stalls should give to each horse less than 800 or 1,000 cubic feet."

Youatt wrote: "It is not generally known, as it should be, that the return to a hot stable is quite as dangerous as the change from a heated atmosphere to a cold and biting air. * * * It is the *sudden* change of temperature, whether from heat to cold or from cold to heat, that does the mischief and yearly destroys a multitude of horses."

One more quotation, from John Osgood, who, in speaking of city stables, said: "Now, in the name of humanity and ordinary commercial thrift and sagacity, let this be stopped. There is no reason why stables should be horse hells! No reason why they should vie with 'The Black Hole' in their inevitable cruelty, and gloom, and destruction. These and city stables generally (with some exceptions) are a disgrace and a shame to a civilized community. So long as they continue as they now are, horses must die. There are no remedies for the sudden and violent diseases which will attend such poisonous air and water and food. The remedy lies in providing ample and well ventilated stables—stables well lighted, with stalls of ample dimensions, with escape pipes for the ammoniacal effluvia which arises from so many animals and their excretions, with more room for evaporations; and then the chances would no longer be against every horse who passes through these doors, as they were agains, those ghastly ones who passed through Dante's gate, and, as they went in, read above their heads:

'Who passes here goes into everlasting hell.'

"Improve the stables, then, and prevent disease. * * * Do not insult a respectable animal who has come from the country to do his share of the work of the world, and has brought with him the memory of the sweet hills and skies, at least, by immuring him in one of those cramped, rickety, rotten, stinking, slovenly, damp dungeons, where a dumb beast would lose his self-respect and his courage beneath an oppressive weight of miasmas and hideous, gloomy, nasty confusion. Stop this, or pray that horses may die ere the evil days come."

The above, if it have weight, must convince you that badly-constructed stables are responsible for many, very many, of the diseases among horses. The paramount importance of abundant sunlight, perfect sewerage and good ventilation is now, fortunately, recognized almost universally in building human habitations, but how often ignored in providing quarters for the horse, the number sick and unfit for duty most eloquently testifies.

I will now describe a stable just finished for the North Chicago City Railway. It fronts south 125 feet upon Belden avenue, east 238 feet upon Jay street, both of which streets are 66 feet wide. Along the west side there is an alley 16 feet wide, and 50 feet left vacant, extending to the Car House. On the north our property extends 12 feet beyond the stable. We therefore have light and ventilation upon four sides. The horses face north and south. In the rear of each row of horses there is an alley extending clear across the stable, 10 feet wide, with a sash door 7×10 feet at each end. Another alley 9 feet 6 inches wide extends the length of the stable at right angles to the former, with sash doors 7×10 feet at each end. The stalls are 9 feet deep and each horse is allowed 56

inches of width. Double stalls are, in my opinion, the best, when horses will stand quietly together. So many of our horses will not do this, that I alternate two single stalls with one double stall, thus allowing the foreman to place the horses who will not stand quietly in single stalls. The floor of this stable consists of four inches of asphalt with 2×4 inches scantling bedded therein ; 16 inch centres, to which the wearing floor of 2-inch pine is spiked. The stalls have an inclination of 2 inches, terminating in a gutter connected with the sewer. These gutters are covered with cast iron plates 56 inches long by 6 inches wide, perforated to allow the urine to pass into the gutter. These covers are movable and at least once a week the foreman of the stable sees that they are taken up and that the gutters are thoroughly cleaned. Some disinfectant should be freely used. Between each row of horses there is a "feed alley" four feet wide. By this construction the horses are not brought head to head to breathe each the other's breath, contaminated, it may be, by disease which is thus spread from one to another. No food is wasted in placing it in the manger ; and there is less danger of an employé being injured or perchance crippled for life by some vicious or frightened horse. At each end of these feed alleys windows are placed containing 32 lights 9 × 14 inches, a size of galss I have adopted as a standard and use whenever possible, to avoid carrying a stock of different sizes. In these feed alleys beneath the floor there are placed fresh-air ducts, extending from outside to outside of the stable, through which air is admitted, passing out into the stable through perforations in the cover, thus avoiding injurious draughts. Its exterior openings are protected by cast-iron grates built in the brick work, preventing the entrance of all vermin, and especially the pestiferous rat! In this stable there are 9 ventilators, one located at the intersection of all alleys, for the exit of foul air. They are 6 × 6 feet at the lower end and taper to 4 × 4 feet at the top, extending 8 feet above the roof. The four sides above the roof are movable (except the posts), inclining at an angle of 45°, thus deflecting the air upward and doing away with all downward currents and permitting the opening to be reduced in cold or inclement weather, ropes extending to the ground floor for this purpose. We are indebted to the veteran in horse railroad matters, John Stephenson, for this admirable idea. It resulted from many experiments made by him upon ventilation while a member of the New York School Board. The gas burners located under these ventilators assist in ventilation by heating the air, which ascends and increases the outward-bound current of impure air.

The first story of this stable is 16 feet high, second story 7 feet at walls and 9 at centre. Each horse has twelve hundred and sixteen cubic feet of space, an amount fully equal to modern theory requirements. The hay loft can contain one year's supply if needed. The feed department, with bins for storage, troughs 16 feet long, 4 feet high, and 3 to 4 feet wide for mixing feed, cut-hay room and horse power to run the cutter is located upstairs. As we use shavings for bedding and can obtain them cheaply and abundantly in summer when the mills are busy, whereas they are scarce and high in winter, the bedding room is large. On the ground floor it is 16 × 50 feet and extends open to the roof, with an addition,

16 × 70 feet, on the second floor. The cost of bedding for the horses purchased in this way is one half cent. per diem each.

The hospital, separated from the balance of the stable, is located at the north end, in the most quiet spot. Scales are provided upon which all supplies are weighed. An office for the foremen, room for grooms, another for conductors, and one for storage, are furnished, besides convenient closets, etc. I neglected to state that a number of catch basins are provided to retain all shavings and solid matter that might otherwise get into and obstruct the sewer pipes. These basins are four feet in diameter, and are cleaned out as often as may be necessary. They are trapped to prevent sewer gas from entering the stable ; all the roof water is used to flush these sewers. The building will be whitewashed in the fall, for health and comfort.

The above brief description will serve to give you an idea as to how far I have succeeded in putting in practice the requirements of theory. The stable has abundance of fresh air, contaminated air is removed, and there is good sewerage and plenty of light. The small percentage of horses in our hospitals most emphatically indorses the construction.

I think with Youatt that the stable should not be too warm in winter. Nature is a safe guide, and she provides the horse with a suitable covering. The stable temperature in my opinion should not vary more than 10 or 20 degrees from the external air. Keep the stable cool and, if necessary, throw a blanket over a horse while hot, just in from work, during severe winter weather. Our car horses pass twenty of the twenty-four hours in the stable, and the importance of thorough sanitary arrangements is, of course, thereby increased, as the majority of horses used in other lines of business spend scarcely more than one-third as much time in the stable.

"A merciful man is merciful unto his beast," but the most refined selfishness, if intelligent, should cause each and every one with capital invested in horse-flesh to give it "suitable stable accommodations." Were my pen capable of expressing all I feel, most eloquent would be my appeal in behalf of the noble brute for whom I have ever entertained the deepest affection.

EVOLUTION OF THE ELECTRIC RAILWAY:

ITS COMMERCIAL AND SCIENTIFIC ASPECT.

By Dr. Wellington Adams, Member of the Engineers' Club of St. Louis.

[Read April 23, 1884.]

[*Continued from page* 264.]

We must consider something besides the mere propulsion of a car. Electricity possesses innumerable novel and superior qualities or features which have never heretofore been presented to the railway constructor, although fully appreciated by railway economists. It behooves us to grasp and make the most of these. To be sure, some kind of operation may be for a while attained at maximum outlay, in a primitive impractical manner, but that which should be striven for is maximum

economy as regards mechanical return, and such perfection in operation as will insure a minimum wear and tear. The application of electricity to railway propulsion means a complete revolution in railway construction and manipulation. In dealing with electricity as an agent of locomotion, it is unnecessary that we should adhere to those methods and processes which experience has demonstrated as essential to steam locomotion. On the contrary, having a totally different element to deal with, new problems are presented, and new principles involved. In handling the question of steam locomotion, Stevenson, after giving preference to the principle of traction over cables, concluded that it would be decidedly best to apply the power directly to each axle, or, better still, to each wheel of every car, and operate each car separately. Finding such an arrangement impossible, however, he next decided upon making each car at least its own locomotive. But this system also proving impracticable with steam, he, as a *dernier ressort*, adopted the "train system," with its ponderous locomotive. Had Stevenson and his followers found it as practicable with steam as we now find it with electricity to apply the power direct to each wheel, the long "train system" of locomotion would never have been instituted. One of the first requirements, therefore, of an electric railway system embodying the elements of permanency and commercial success, is the abolishment of the locomotive and its essential dead weight, which in turn does away with the "train system" and its numerous objectionable features. When a number of cars are coupled together their wear and tear and weight are necessarily greater. The impetus of a train being thus increased, it becomes more difficult to stop it, and the results of an accident are more disastrous both to life and property. The amount of air always carried between the cars of a train offers great resistance, All curves must be of higher degree than would otherwise be necessary, and a very much larger percentage of power is lost in making the curves than would be the case in a system applying the power to each wheel or axle. In the train system, if one car catches fire or jumps the track, others are very likely to do the same, and thus again is the company's yearly expense greatly increased. The cars being individually heavier, and the necessity of providing for the weight of the aggregate number of cars massed together in the train system, increases the cost of the road-bed and all culverts and bridges. When we dispense with the locomotive and its attendant dead weight, we abolish the cost of the power consumed in propelling the same, and we greatly lessen the principal cause of wear and tear of the road-bed, culverts, bridges, etc., and, furthermore, we render possible the use of much lighter rails, and thus again further reduce both the first cost of construction, or the capital invested, and the cost of operation. Cars which are not being continually bumped together and wrenched to pieces by a heavy train may certainly be built lighter. In the locomotive train system the weight which must be provided to supply a proper amount of adhesion between the rails and the wheels is a *dead* weight, requiring as much power for its propulsion as is required by the remainder of the train; in fact, nineteen tons of dead weight must be hauled for every ton of passengers carried. Furthermore, this necessary dead weight is a fixed quantity, and does not vary with the actual paying load to

be hauled. The adhesive power and its attendant dead weight to be propelled remain the same whether the accompanying cars are but one-tenth filled, or fully loaded, and railway statistics show that the average number of passengers carried by each train is but 70; whereas in a system having the tractive power distributed, whether the cars be run singly or in trains, the weight which gives the adhesive power is more nearly proportionate to the load to be carried; and the weight which contributes this adhesive power is not a dead weight, but one that the operators of the road receive pay for. As each passenger enters a car, an additional weight is supplied for the exertion of just as much extra traction between the rails and the wheels as is required to propel such an increase in the load.

Here, then, we have an expenditure directly proportionate to the demand, the height of economy being thus attained. A no less important indication in railway propulsion looks to the application of the power *directly* to the point where it is to expend itself. Be this never so desirable, however, such a thing is impossible with steam, but in every way practicable with electricity—indeed, electricity seems here to have found its grandest and most important application. Again, an all-important indication for a successful electric railway may be said to lie in the fact that an electro-dynamic machine, when operating with greatest economy and safety, must, like a generator, run at a predetermined maximum speed. Hence, provision must be made for varying the speed of the car by some other means than by varying speed of the electric motor. Means must be provided for allowing the armature, or that portion of the electric motor which revolves at a high speed, to attain full headway independently before any load is placed upon it, and the latter should be applied gradually, in order to avoid jerks. In addition to the economy and safety insured by this arrangement, we, in starting, allow advantage to be taken of the impetus of the motor in overcoming the inertia of a car, and, furthermore, we do not compel the motor to do its work rapidly, since it is a *sine quâ non* of an electric motor that it shall do its work slowly. Thus will it be possible for an electric car to attain maximum speed almost at the start, whereas from an eighth to a half mile is required for a steam engine to acquire its running speed. This one point alone renders electricity, when properly applied, particularly suitable for city surface and elevated roads, where frequent stops are necessary.

It must also be possible to vary the quantity of electricity running through the car, or, rather, of varying the quantity tapped from the main supply, without introducing useless resistance. There must, furthermore, exist at the central or generating station an automatic regulator, or equivalent arrangement, which will keep the supply of electricity in the mains always proportionate to the demand, and which shall regulate the amount of fuel consumed in the steam engine so that it likewise will be proportionate to the power or electric energy absorbed throughout the system.

But little, if anything, has been done toward developing the electric railway outside of what Dr. Siemens did in 1879, namely—the simple mounting of an electro-motor upon a car and connecting this up by means

of a leather or chain belt or by a train of cogs, with the car axle. Siemens at first built an electric locomotive, but we notice he soon abandoned this principle and began mounting his machines on each car and connecting these up with the axles by means of belts. Evidently, his discerning mind soon grasped the situation, and he began applying the power in a way better calculated to develop the superior advantages of electricity.

Edison and Field, however, have adhered to the locomotive principle and train system, as witness their exhibitions at Chicago and Louisville.

It certainly requires but little mechanical knowledge to appreciate the weak points about all these.

In the first place, either the cars must be mounted upon their axles rigidly without springs, or else the motor, which is mounted upon the car, and the axles with which the motor is geared, will move differently and will not always be in line.

Second, no form of belting will do for a practical commercial railroad—that is simply out of the question, as every engineer must concede at once.

Third, gearing between parts which move differently and are constantly getting out of line, is also impractical.

But little has been done toward thorough insulation for the conductors and in devising a practical moving contact.

Absolutely nothing has been suggested as a means of economic regulation, in every instance useless resistance being used, and the current wasted in useless heat.

To recapitulate:—Among the many advantages of electricity properly applied as a motor over steam for passenger transport, is the circumstance that no heavy machinery or fuel has to be carried about to set the train in motion. The carriages running singly may be built much lighter, thus reducing the power necessary to move them; reducing the noises made in running, greatly lessening the wear and tear of both tramway and rolling stock; reducing the first cost of cars: reducing the force required to brake the cars when going at a high speed, the impetus being less; reducing the force of concussion in case of accident, and hence, the dangers and destruction to life and property consequent thereon; and, finally, permitting all bridges and other superstructures to be built more cheaply, more artistically and less weighty, than has heretofore been possible. Furthermore, for the same reason, and also because of the distribution of motive power attainable, greater speed may be acquired, sharper curves rounded with less than the usual wear, and steeper grades may be climbed. Experienced and trained engineers and firemen are not required to operate an electric railway. Any boy possessed of ordinary intelligence may be taught in half an hour to manage a car perfectly and cause it to perform all the work of a steam locomotive. This feature alone does away with a great source of expense now incurred by all steam railways, whether elevated or surface. The electric system also admits of the use of large, stationary, protected steam engines of the most economical type. The use of these as against small, exposed, portable ones, reduces immeasurably the wear and tear, as well as first cost, and also the amount of fuel necessary to develop a given amount of power ; and if water power be utilized—as would very

frequently be possible—the cost of operating such a railway system can be reduced to a comparative minimum. Further advantages are: Ability to get up speed quickly, which is particularly desirable for street and elevated roads; absence of noise; freedom from liability to many forms of accident now unavoidable, and from the annoyance of flying sparks, cinders, smoke, gases, grease, and the many other offensive and dangerous accompaniments of our steam railway system.

The time is now surely at hand for the economic and advantageous employment of electricity as a cleanly and cheap means of effecting rapid passenger transportation through densely populated cities and across the continent. Jacobi, Davenport, Davidson, Little, Pinkus and Page were in advance of the age in which they lived. No more rapid transit was demanded at that period of the world's history. The dynamo-electric machine, which we have seen has rendered feasible the electric railway, was not then in existence; hence they were obliged to apply electricity as a primary motor, an office which is filled far more economically by the steam engine, as was shown by their contemporaries in science, those versed in mathematics and thermo-dynamics. Now, however, the time is ripe for its introduction. We have reached the period of transition from the stage of practical demonstration to that of practical application. We now know how to apply electricity as a *secondary* motor; the dynamo-electric machine has been introduced as an industrial feature of our age; the project of electric railway transportation *now* has the sanction and enthusiastic support of the learned in the sciences of electricity, dynamics and mathematics; and lastly, we live in an age which demands more rapid transit. We think fast and live fast, and this naturally begets an almost insatiable desire and necessity to travel fast. Railroad managers are expected to provide the means of gratifying this desire with safety to passengers and without detriment to their earnings, if possible; but at all hazards to put trains through according to the latest and fastest schedule. For a number of years the regular time between New York and Chicago has been thirty-six hours, or a speed of twenty-five miles an hour, including stops. This is not what might be called slow, but the impatient public is more than ever impressed with the idea that "time is money," and that something better than this should be accomplished, in view of the improvements in rails, road-beds and rolling-stock. Managers, in order to meet this demand, are put to a terrible strain. They must provide the ways and means, head off competition, take the responsibilities and risks of accidents, and, what is more important than all, they must make the traffic pay.

This last requisite, in the face of rival fluctuating rates, the enormous dead weight of locomotive and tender, of sleeping and drawing-room cars, and the excessive wear and tear of track, superstructure and rolling-stock, from the increased weight necessary to effect such rapid transit *with the steam system*, is not an easy thing to respond to. Managers, master mechanics and car builders have for a long time regarded the rapidly increasing weight of trains as a growing evil that should be checked to prevent expenses from swallowing up earnings in passenger traffic. Fast running under existing conditions is extremely hazardous

as well as expensive, and this simply because of the enormous weight given to railway trains. The tractive force of twenty to sixty tons exerted by the driving-wheels of a locomotive on an eighth of an inch of rail, soon tears a tramway to pieces. These conditions are practically reversed in the writer's electric railway system. It might almost be said that here the lighter the rolling stock the greater the possibilities as to speed. Calculations based on the numerous points of advantage herein specified show that an electric railway may be operated at an average speed of sixty miles an hour for one-third the cost of operating by steam at the same speed.

If the train system must be discarded as least calculated to develop the advantageous qualities of electricity as applied to railway propulsion, then a practical method of applying this power upon each car must be devised, and this has by many eminent engineers been found to be no easy matter, but, on the contrary, a most complex question, fraught with many difficulties. The armature of the electric motor must run at a high speed, and its power must be transmitted to the wheels of the car by a *positive* gearing. All forms of belting were at first sight seen to be entirely impracticable; while gear wheels between parts moving differently were not to be considered. Everything electrical and mechanical, including that fundamental law of mechanics which directs that power shall in every instance be applied as *directly* as possible, seemed to point toward a direct application to the wheels. But how was this to be accomplished? As we have before noted, the armature or revolving part of the electric motor must move at a very high speed, entirely too high for the speed of a car wheel. And, furthermore, it is very evident that it was impossible to construct an "armature" upon the modern dynamo principle which should also serve as a car wheel—such a dual function was out of the question. And yet it was imperative that the principle of the motor should be that of the most efficient type of the modern dynamo.

However carefully the reader may examine into our simple solution of this question, no adequate conception can be formed of the amount of thought and work which has been bestowed upon it.

We have succeeded in applying the power directly to every wheel, to the point of traction, where the power is absorbed, the work done, and yet our wheel is neither an "armature" nor a "field" of a dynamo. It is both combined! In other words, every wheel is a dynamo in itself. Each wheel is *animated*, having power within itself. Hence every wheel becomes a veritable locomotive. Let us for a moment look into the construction of this anomaly. It is composed of two parts, one constituting the "field" of the motor, and at the same time serving as the tire supporting portion of the wheel; while the second part represents the "armature" of the motor, and revolves within, and in an opposite direction to, the first. Hence it will be observed that the wheel is formed of two separate and distinct parts, both of which revolve, but in opposite directions. Both parts have a continuous tendency to pull toward each other, the poles of the two electro-magnetic rings, or inductors, being always kept at a minimum distance apart. The two electro-magnetic rings mutually act upon each other inductively throughout their entire

length. The inner ring corresponds to the armature of a dynamo machine, and revolves as 3 to 1 of the outer ring, which latter in turn corresponds to the field of a dynamo (Fig. 1). Their relative speeds are maintained through the agency of an epicycloidal train of either friction or toothed gearing, the internal gear being carried by the outer ring or field, while the central, or "sun-wheel," is mounted upon the hub of the armature with an intermediate friction clutch. The intermediate, or floating wheel is carried by a frame, forming one with, or rigidly attached to, the car axle-boxes. Thus do all geared parts move together always in line. The armature is mounted upon a hub in the form of a sleeve, which revolves upon the car axle.*

Here we have the weight of the machine directly at the point of traction—the tractive power is distributed to every wheel and thus applied directly to the point of traction. The armature may revolve independently of the wheel—hence it may be allowed to attain a high velocity before

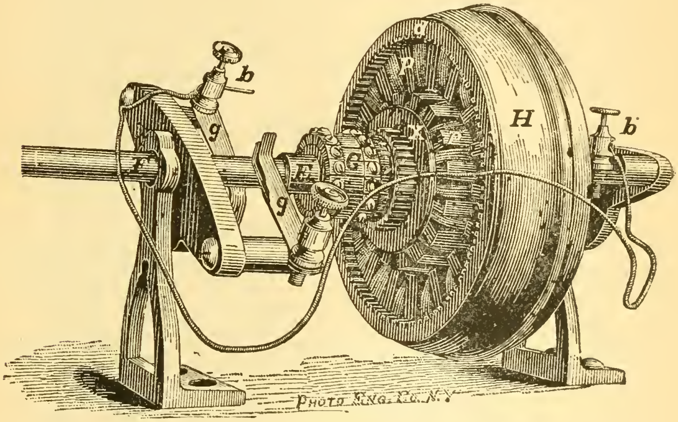


FIG. 1.

applying the load, which can be applied slowly and advantage be taken of the impetus of the armature to overcome the inertia of the car on starting. Thus also are we not obliged to jeopardize the life of the armature. Again, we are by this arrangement afforded a purely mechanical means of controlling the speed of our car without introducing useless resistance, since by allowing a slip at the friction clutch the armature will run at a proportionately higher speed and generate a higher counter E. M. F., which acts as a resistance and allows less current to pass through the machine, while at the same time the machine is working more efficiently, since its E. M. F. is approaching nearer the E. M. F. of the generator or line. In moving the field as well as the armature we produce an effect equivalent to increasing by one-third the number of sections in the armature beyond what is mechanically practical, and thus do we raise the electro-dynamic efficiency of the motor. The construction of the motor also is such as to greatly increase the leverage through which

*The lecturer here showed several models in operation.

the work is done, the pull between the armature and the field being at a considerable distance from the centre. Again, the electro-magnetic construction is such that the armature and the field are subjected to each other's inductive influence throughout their entire length.

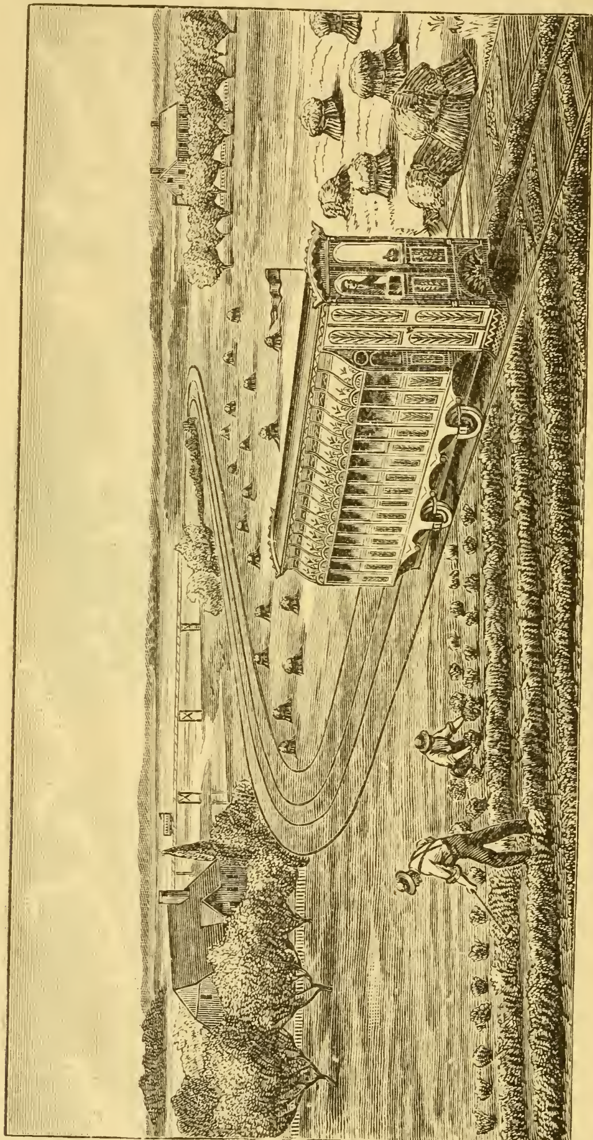


FIG. 2.—FROM A PHOTOGRAPH OF A MODEL IN OPERATION.

This animated wheel is particularly well adapted to one-rail elevated roads, and there is no telling what speed might be attained with wheels like this of from 4 to 6 feet in diameter. In anotherform I have taken

the field from the wheel and made it stationary around the axle between the wheels, the armature revolving as before on the axle, the whole forming an electric truck (see Fig. 3), which is in no way attached to the car, and which may therefore be removed from under or placed beneath a car at pleasure in a few minutes. Here also, all parts are in line and move together, since the field is rigidly attached to and forms one with the car-axle box. The power is here transmitted through an epicycloidal train of friction gearing at each end of the armature.*

We come now to a detailed consideration of the question of percentage of return. The return of a "dynamo" machine with regard to another which puts the first in motion is expressed by the proportion of the useful mechanical work developed by the second to the work absorbed by the first. This may be estimated in two different ways: First, by applying a dynamometer to the generating machine and a Prony brake to the motor; second, by measuring the intensity or quantity of the current traversing the two machines. In the latter case, the mechanical work absorbed by the first machine and that returned by the second may be ascertained by the electric measurements taken, if we but apply certain fundamental dynamic theorems. Of necessity, such a return would be somewhat

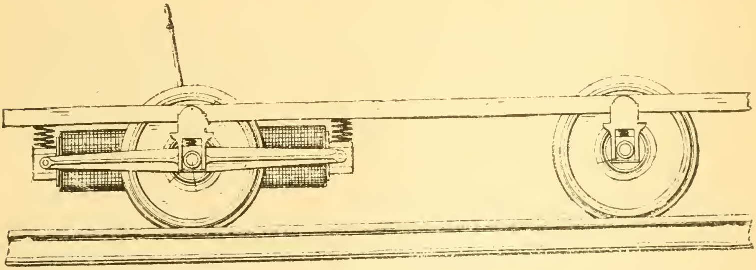


FIG. 3.

higher than that obtained by direct mechanical measurements, since it is simply that which we should obtain in practice if the two machines were perfect, that is, free from friction and certain electric imperfections. Unlike the steam engine, however, which returns us but 10 per cent. of our energy in the form of available work, we get in the electric engine a return of 90 per cent., the above mentioned sources of loss consuming but 4 or 5 per cent. By Joule's law we can easily calculate the mechanical work developed in the form of heat in an INERT circuit. This is expressed by one of these three formulæ, $R\,I^2$, $\frac{E^2}{R}$ or $E\,I$.

The first supposes the resistance (R) of the circuit and the quantity (I) to be known; the second supposes the electromotive force or pressure (E) and the resistance (R) to be known; and the third supposes the electromotive force (E) and the quantity (I) to be known. The last two may be deduced from the first, observing Ohm's law $I = \frac{E}{R}$.

Suppose now that instead of the circuit being INERT it contained a per-

* The electric railway truck was here shown in operation (see Fig. 3).

fect electric motor (the Pacinotti type) free from friction, etc., and provided with a brake.

The total energy developed by the source of electricity now appears in the whole circuit in two different forms : heat and work. The quantity of the current being the same throughout the circuit, the heat developed in the whole circuit is expressed by $\frac{R\,I^2}{g}$.

The total quantity of the work generated and expended in the circuit is expressed in kilogrammeters per second by $\frac{E\,I}{g}$.

Supposing now T to be the mechanical work produced by the motor expressed in kilogrammeters per second. Then, since the total energies developed by the source equal the sum of the partial energies developed in the whole circuit, we have the equation $\frac{E\,I}{g} = \frac{R\,I^2}{g} + T$; whence it follows that we have $T = \frac{I(E - R\,I)}{g}$, where $E - R\,I$ represents a negative E. M. F. (e). Hence we conclude that where a motor performs work it necessarily generates a counter E. M. F., and this, experiment proves true.

We are now, therefore, brought to the equation $T = \frac{e\,I}{g}$, or remembering that $I = \frac{E - e}{R}$ $T = \frac{e\,(E - e)}{g\,R}$, so that the total energy developed by the source becomes $T = \frac{E\,I}{g} = \frac{E(E - e)}{g\,R}$, and the work lost in the form of heat $\frac{R\,I}{g}$ or $\frac{R}{g}\left(\frac{E - e}{R}\right)^2$ or $\frac{(E - e)^2}{g\,R}$.

These expressions constitute the fundamental equations of the theory of the electrical transmission of power. Dynamometric measurements have of late proved that the expression $\frac{E\,I}{g}$ represents about .95 of the mechanical work applied to the pulley of the generator after deductions are made for the work expended in overcoming friction ; that is to say, if the total work applied to the generator is represented by 100, and the work absorbed by friction by 10, the product $\frac{E\,I}{g}$ may reach $\frac{95}{100}$ of the remaining work (100 — 10) absorbed in purely electric work, or 85.5 per cent. The difference, 90 — 85.5, then represents the loss due to electric imperfections, which I have already said amounted to 4 or 5 per cent.

These fundamental equations enable us to calculate the value of the economic return. For if we call k this return, then $k = \frac{e\,I}{g} \div \frac{E\,I}{g} = \frac{e}{E}$.

You notice then that this expression is *independent* of the *resistance* (R), so that we may conclude that the economic return depends only upon the proportion between the counter electromotive force of the motor and the positive electromotive force of the generator. This is what M. Deprez tersely expressed when he said, "The return is independent of the distance." The *absolute work*, however, is not independent of the distance. If we would maintain constant the work transmitted, whatever the

resistance or distance, M. Deprez has shown that the electromotive force of the source must be increased proportionately to the square root of the resistance. It is a misunderstanding of this point which has led some superficial critics to dispute the results of M. Deprez's work. No rational person would advocate the possibility of transmitting the power of Niagara over a telegraph wire for an unlimited distance. Neither can I conceive of an instance where one would think of putting in a plant to transmit 10 H. P. over a telegraph wire to a point distant 25 miles from the source. Surely, no one would think of establishing a plant for the hydraulic or pneumatic transmission of 10 H. P. to a point distant 25 miles. Why, then, should such absurdities be expected of electricity? In order to see the influence of resistance in the circuit on the absolute work, we must introduce into these equations the value of the return k which it is *desired* to obtain. From the equation $k = \frac{e}{E}$ we have $e = k\,E$, and making use of this value e in the preceding equations, they become:

Work absorbed in generator, $\frac{E^2\,(1-k)}{g\,R}$

Work recovered in motor, $\frac{E^2\,k\,(1-k)}{g\,R}$

Work lost in the form of heat, $\frac{E^2\,(1-k)^2}{g\,R}$

Thus, the absolute work of the receiver may be the same in two different experiments, although the economic return has very dissimilar

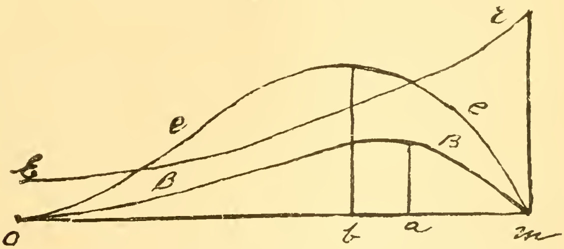


FIG. 4.—KNAPP'S DIAGRAM FOR POWER AND EFFICIENCY.

Speeds are plotted as abscissæ, and the electrical work absorbed in watts divided by 746 as ordinates. Then with series wound motors we obtain curve $E\,E$, the shape of curve depending on type of motor. Variation of speed obtained by loading brake with different weights. Maximum speed $O\,M$. There is a speed at which the external work is a maximum. After loading the brake with varying weights, plot resulting speeds and horse-power as abscissæ and ordinates, which produces the curve $B\,B$. $e = \frac{B}{E}$ made with arbitrary scale gives commercial efficiency. Speed for maximum external H. P. is $o\,a$. Speed for highest efficiency is $o\,b$.

values. These differences result from the weight put on the brake. According as the weight on the brake is great or small, so the speed of the receiver is low or high, but the work per second may be the same. This work also may be nil in two cases—when $k = 0$, and when $k = 1$.

This diagram (Fig. 4) very beautifully illustrates geometrically the relationship which exists between the work done and the efficiency, as also the relationship between e and E.

We see from this that there is a value for the economic return, for which the useful work of the motor is the greatest possible. The sum of the two expressions k and $1 - k$ being constant, this maximum is reached when they are equal; that is to say, when $k = \frac{1}{2}$. This further gives the result $\frac{E^2}{g R} (1 - 2 k)$ of the second term of the second equation. The useful work received therefore becomes $\frac{E^2}{4 g R}$, and the work spent in the generator $\frac{E^2}{2 g R}$. If the receiver were prevented from turning we should have $k = 0$, and the work absorbed by the generator then becomes the greatest possible, or $\frac{E^2}{g R}$, the identical value we found for an inert circuit. From this we see that the maximum mechanical work developed by the receiver corresponds to the economical return, being equal to one-half, and that when the economic return is varied between 1 and zero the work spent in the generator constantly increases from zero to $\frac{E^2}{gR}$, although the electromotive force remains constant.

It is from not having well comprehended these simple considerations that many have lately written a vast amount of inaccurate criticism on the electrical transport of force. For example, one of the most common of errors is the belief that the economic return can never exceed 50 per cent., because it reaches this value when the work developed by the motor or receiver is the greatest possible in value. We have analogous conditions in thermodynamics, why not apply such reasoning in their case? Take a case in point now of two precisely similar machines, one acting as generator, the other as motor. Remembering that the current is equal throughout the circuit and that a constant current produces a uniformly constant field, and that the E. M. F. of a particular generator depends upon its speed and the strength of its field, then it follows that calling the corresponding electromotive forces and speeds of the two machines e, E and v, V respectively, and k the return, we shall have $\frac{e}{E} = \frac{v}{V} = k$. We thus come back to the value $\frac{e}{E}$, which we have already obtained for the economic return by quite a different method.

Regarding the recent experiment of M. Deprez, when it is remembered that before this experiment the boldest enterprise in this direction was a 4 millimetre *copper* wire, 6,400 metres long, with a resistance of only 8.4 ohms, carefully insulated throughout its entire length, and that M. Deprez chose an iron telegraph wire exposed to the rain, 114,000 metres in length, with a resistance of 950 ohms, and that notwithstanding these enormous differences in the conditions of the two experiments, the same industrial return was obtained, namely, 50 per cent., it will be conceded that the Miesbach-Munich experiment was of the utmost importance in the history of the transport of force. In this experiment, notwithstanding the high electromotive force employed (1400 volts) and the poor insulation of the line, not one per cent. of the current was lost by leakage. It is extremely unfortunate for the engineering profession and

the people at large that M. Deprez has been so misunderstood, for it has resulted in the creation of some very erroneous impressions in the minds of some engineers concerning the electrical transmission of power. Let me cite an instance in point: Perhaps some of you have noticed a paragraph going the rounds of your journals to this effect: "M. Deprez has succeeded in transmitting a current of electricity equivalent to 5 horse-power, along a telegraph wire one-sixth of an inch in diameter, some ten miles long, with an expenditure of 29 per cent. of the power. Compared with wire rope, this means falls short in actual *efficiency* (mark you, *efficiency*), since Messrs. Hems send 500 horse-power along a $\frac{3}{4}$-inch rope. Such logic is ridiculous and should not find place in scientific journals. Pray tell us, in the first place, what has the *efficiency* to do with the respective sizes of the conductors in the two systems; and second, one might as well impose upon the teledynamic advocates that they transmit their 500 horse-power by means of a $\frac{3}{4}$-inch twine, as to impose upon the advocates of electrical transmission the necessity of using an iron wire $\frac{1}{6}$ of an inch in diameter for the transmission of the same power. As a matter of fact we can transmit electrically 1,340 horse-power over a copper conductor of but $\frac{1}{2}$ inch in diameter, a distance of five miles, with a loss of but 10 per cent. in the line. Aside from the difficulties attending its subdivision and application, the transmission of such an amount of power by a wire rope of like size and over a corresponding distance would be impossible.

We come now to a practical application of these data.

Suppose we wish to determine whether it will pay to operate a street railway by electricity: Knowing the horse-power which the motor must develop in order to move each car or train over the given maximum grades at a given speed, and knowing the greatest current the conductor we provide can carry without losing more than the prescribed amount, it remains to calculate the electromotive force which the motor must develop.

Supposing the electrical efficiency of the motor to be eighty-five per cent., then $H = \frac{Ie}{746} \times \frac{85}{100}$, because the counter E. M. F. (e) generated by the motor multiplied by the current traversing it measures the *electrical* work it performs. Then $e = \frac{H \times 746}{I} \times \frac{100}{85}$

In order to find the E. M. F. of the generator (E):

$$\frac{E}{e} = \frac{W}{w} = \frac{Ie + I^2 R}{Ie} = 1 + \frac{IR}{e}\ ;\ E = e + IR.$$

Upon these and the preceding expressions are based the following estimates as to the comparative cost of operating a street railway by horse power, electricity and cable:

COST OF OPERATING ELECTRIC SYSTEM.

44 *Cars.* *Speed*, 6 *Miles.* *Length*, $5\frac{68}{100}$ *in.*

22 cars acting as locomotives, each one having an additional car attached, and being provided with 8 horse-power.

22 cars, 8 horse-power, multiplied by 2, on the supposition that we get but 50 per cent. return instead of 70, as is possible, = 352 = total h. p.

consumed when all the cars are running and consuming full 8 horse-power, a condition which never exhibits—even at such times when the road is working at maximum capacity.

Average power consumed during the running hours,	200 h. p.
Pounds of coal consumed, five horse-power per hour,	$2\frac{1}{2}$
Total amount of coal consumed per hour,	500 lbs.
Working hours per day,	20 hours.
Pounds of coal consumed per day,	10,000 lbs.

Cost of coal per 1,000 lbs., $1.00.

First Item—

10,000 lbs. of coal at $1.00, $10.00 = cost of coal per day.

Cost of coal per year		$3,650
One engineer at	$5.00 per day.	
One assistant engineer at	2.50 " "	
One electrical engineer at	5.00 " "	
One assistant electrical engineer at	2.50 " "	
Two stokers at $2.50	5.00 " "	

Second Item—

Total cost of labor at station per day	$20.00
Yearly cost of labor at station	7,300

Third Item—

Yearly oil and "waste."	$500.00

Fourth Item—

One conductor to every 2 cars at	$2.00
One driver " " "	2.00
Cost of labor on each train	$4.00
No. of trains	22
Total cost of labor on cars per day	$88.00
Total yearly cost of labor upon cars	$32,120.00

3 steam engines of 208 horse-power each	$7,500.00
Fittings for same	1.500.00
2 Babcock & Wilcox boilers of 460 horse power	8,500.00
1 Babcock & Wilcox boiler of 146 horse-power capacity	4,070.00
Fittings for boilers	1,000.00
Extras	1,000.00
Total net	$23,570.00

Four electric circuits of $2\frac{3}{4}$ miles each, having conductors with electrical capacity of 500 ampères and having a resistance of but $\frac{1}{5}$ of the entire line, where each generator and each motor has a resistance of 10 ohms, and of which there are 11, arranged in multiple circuit, equal a copper bar of $\frac{1}{2}$ inch in area, costing, at 30 cents per pound :

Cost of copper conductor per mile	$2,890.00
No. of miles	11
	$31,790.00
Cost of conduit and tramway per mile of double track	$40,000.00
	$2\frac{3}{4}$
	$110,000.00
Electro-motor fittings to 22 cars at $1,000 each	22,000.00
22 electric generator motors at $2,000	44,000.00
4 surplus generators	8,000.00
Total cost of generators	$52,000.00

Wear and tear on item of motors at 8 per cent	$1,320.00
Wear and tear on generators at 4 per cent	2,000.00
Wear and tear on engines and boilers	3.000.00
Wear and tear on cars, conduit and tramway	11,000.00
	$17,320.00

Total Yearly Wear and Tear.

Wear and tear of conductor	Nothing
44 cars	$50,000.00

Yearly Running Expenses.

Fuel	$3,650.00
Station labor	7,300.00
Waste and oil	500.00
Labor on cars	32,120.00
Wear and tear as itemized	17,320.00
Total	$60,890.00
Yearly interest on capital invested	17,361.60
Yearly expenses, including interest	78,251.60

Capital Invested.

Motors	$22,000.00	
Generators	52,000.00	
Engines and boilers	23,570.00	
Electric conductors (copper)	31,790.00	
Conduit and tramway	110,000.00	
44 cars	50,000.00	
Total	$289,360.00	
Interest at 6 per cent	17,361.60	
Present yearly earnings of road upon which this estimate is based		$177,000.00
Above estimates suppose the work done to be doubled, and, consequently, the income doubled, making		$354,000.00

Estimated from data furnished by a railway company—Present cost of operation with horses—Details of estimate.

22 cars, earning capacity	$177,000.00
Capital invested	$225,000.00
Interest at 6 per cent	13,500.00
Wear and tear at 10 per cent. on invested capital, less cost of horses, the wear and tear of which is included in item of $11,710.20 ; allowing $25,000 to be deducted from the $225,000 as the cost of horses, leaves as invested capital to reckon 10 per cent. wear and tear upon	200,000.00
Interest at 10 per cent	20,000.00
Feed	$31,689.60
Running expenses of stables and contents	11,710.20
Stable expenses	2,185.20
Blacksmithing	2,356.20
Total	$47,941.20
One conductor on each car at $2.00, and one driver at $1.50, 22 cars, cost of labor on cars per day	77.00
Yearly cost of labor on cars	27,874.00
Result:	
Interest at 6 per cent	$13,500.00
Wear and Tear on $200,000 at 10 per cent	20,000 00
Total cost of propelling power	47.941.20
Yearly cost of labor on cars	27,874.00
Total yearly running expenses	$109,315.20
Will average about	$115,000.00

COST OF OPERATING CABLE SYSTEM.

The amount of coal consumed on the Clay street railroad is 3,600 lbs. per day of 17 hours, costing $8 per ton.

Cost of Cable Road Construction.

Will average per mile of double track	$200,000
3 miles	600,000
2 horizontal engines, 14 in. by 30 in., set up	5,800
2 boilers, 52 in. by 16 feet, set up	4,500
Tank, pump and heater	1,500
Compensating arrangement at end of line	1,800
Driving machinery, pulley, etc	6,500
22 cars at $1,000	22,000
22 dummies fitted with grips, at $900	19,800
Engineering sundries, at 10 per cent., in round numbers	25,000
Total cost of three miles complete	$686,900
Interest at 6 per cent	41,214

Cost of Operation.

Maintaining cable per year	$15,000
Oil and waste	500
Maintaining conduit, tramway and cable bearing sheaves, 10 per cent. on $600,000	60,000
Interest on capital invested, at 6 per cent	41,214
In round numbers, 600 tons of coal, at $8.	4,800
	$121,514

Brought forward		$121,514
One engineer at $5.00 per day; one assistant engineer at $3.00 per day; two stokers at $2.50 per day—labor of station per day	$13.00	
Yearly cost of labor at station		4,745
Cost of labor per day, 22 trains	88	
Yearly cost of labor upon cars		32,120
Total yearly cost of operation		$158,379

COMPARISON OF RESULTS.

By Horses.

Capital invested	$225,000.00
Earning capacity	177,000.00
Running expenses, including interest—best year out of 10.	109,315.20

Power consumed, and consequently, the cost of operation the same whether you carry 3,000,000 passengers or 2,000,000.

Want of flexibility as regards ability to regulate the capacity of the road in accordance with the varying demands at different periods throughout the day.

More details to attend to. Such as buying and disposing of horses. All of which makes more clerical work and largely occupies you own personal attention.

More at the mercy of unscrupulous employés, as regards the attention they give your horses.

Want of flexibility of the system renders it necessary to at times overcrowd the car, and thus is the road made unpopular.

Capital confined to street railroading.

By Electricity.

Capital invested	$289,360.00
Earning capacity	354,000.00
Running expenses, including interest	78,351.00

Power consumed, and, consequently, cost of operation, more nearly proportionate to the work done, or, the EARNINGS.

Great flexibility—rendering it possible to exactly adapt the capacity of the road to the varying demands.

After plant is once established, but little attention is required outside of keeping same in repair.

Amount of attention and care given to machinery manifest on the surface.

Great flexibility (that is ability to change the capacity of the road to suit varying traffic) renders overcrowding unnecessary, and have the road become more *popular* and more generally patronized.

Power may be distributed throughout the district amounting to 2,000 horse-power with same street plant and but little additional yearly expense, and bring in an income of over $300,000 a year.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOARD OF MANAGERS.

SEPTEMBER 4, 1884 :—A meeting of the Board of Managers of the Association of Engineering Societies was held at the Astor House, New York, N. Y.

The meeting was called to order by Chairman Benezette Williams at 2:30 P. M. H. L. Eaton was appointed Secretary *pro tem.*

Present : Mr. Benezette Williams, from the Western Society of Engineers, Chicago ; Mr. J. B. Johnson, from the Engineers Club of St. Louis ; Mr. H. G. Prout, Secretary of the Board, and Mr. H. L. Eaton, from the Boston Society of Civil Engineers.

On motion it was voted : That an assessment of $3.00 be made to be paid in installments of $1.00 ; each installment to be based on the mailing list at the time the installment is called for, and be subject to the order of the Chairman.

On motion it was voted : That the names and addresses of the officers of each society be printed upon the second page of the cover of the JOURNAL.

On motion it was voted : That in the opinion of this Board it is desirable that papers read before the societies of this Association should not be published in professional periodicals previous to being published by the Association.

That there is no objection to publishing them in whole or in part in local newspapers.

On motion it was voted : That the Secretary be instructed to insert in the JOURNAL the following :—Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

On motion it was voted : That the Chairman be authorized to arrange for publishing in the JOURNAL an index of engineering reports and society transactions, and abstracts of such reports and transactions as may be found desirable.

On motion it was voted : That the contract with Atkin & Prout for printing the JOURNAL be continued at present rates.

[*Adjourned.*] H. L. EATON, Secretary *pro tem.*

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